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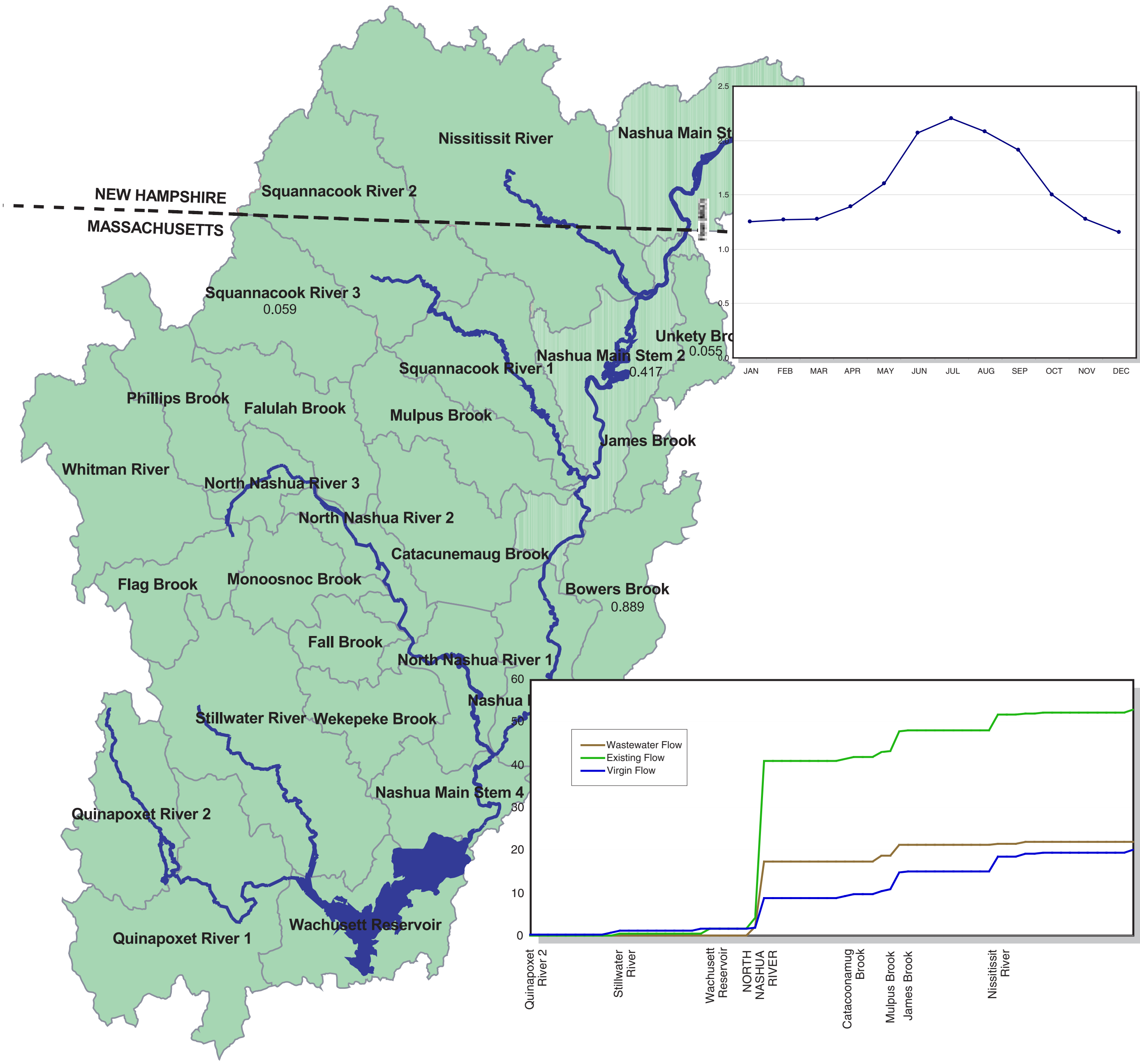
DEM-Office of Water Resources
EOEA - Nashua River Basin Team

Hydrologic Assessment
Nashua River Watershed

June 2002



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Executive Summary

ES.1 Introduction

In 1994, Massachusetts embarked on a new approach to environmental management – the Watershed Initiative. Because the initiative involves the state's coordination of its decision-making process across regulatory programs, the multi-disciplinary Basin Teams were created with the goal of understanding watersheds and the impacts of decisions from various regulatory programs. This study was prepared for and funded by the Massachusetts Executive Office of Environmental Affairs on behalf of the Nashua River Watershed Team in response to DEM RFR #450, as part of the Massachusetts Watershed Initiative.

Available water is a critical component for the future of Nashua River watershed residents and for protection of aquatic resources. Despite being in a water-rich region, many rivers in Massachusetts are severely flow stressed. This project provides the foundation on which future water use decisions can be made in the Nashua River watershed.

The relationship of water withdrawal and wastewater discharge and their effect on river flow is the main objective of this study. In addition, this report examines the effects of future population growth and the associated demand for additional water supply sources and increase in wastewater flow.

The tasks set forth in this report are similar to the river basin plans historically produced by DEM in conjunction with other state and regional planning agencies. The findings of this report are intended to be used as a basis for water management and wastewater discharge permitting and to assess the potential impacts to biological resources of the watershed that may result from consumptive uses of water.

ES.2 Watershed Description

The Nashua River watershed is 538 square miles in area and contains all or part of 31 communities. Seven of the communities are in New Hampshire and the remaining 24 communities are in Massachusetts. Figure ES-1 presents the Nashua River watershed. The communities include older, urbanized cities such as Leominster and Fitchburg and smaller, rural towns such as Ashby and Princeton. The population of many of the towns in the watershed is increasing rapidly, with some having growth rates of 20% predicted over the next twenty years. Flows associated with Devens are accounted for in the flows of the four local communities that make up Devens.

ES.3 Water Supplies

The headwaters of the Nashua River contain Wachusett Reservoir, a major water supply for the metropolitan Boston area. In addition, the City of Worcester has several reservoirs in the headwaters of the Nashua River, which that city uses as water supply. Nineteen communities in the watershed withdraw water either from groundwater wells or from surface water reservoirs for public water supplies. Future

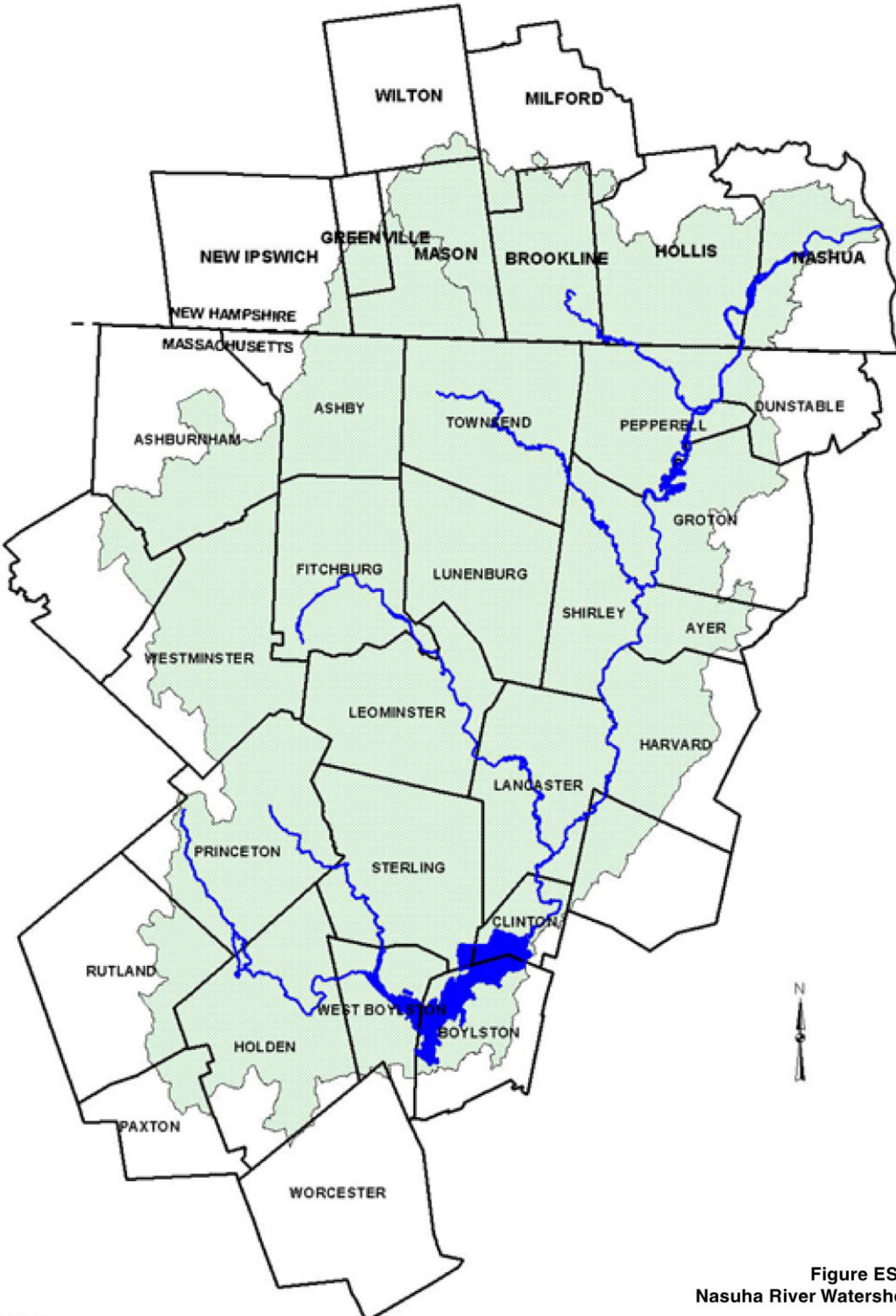

Figure ES-1
Nasuha River Watershed

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growth in these communities will put greater demand on the water resources in the Nashua River.

The existing water suppliers withdraw 183 mgd annually from the groundwater and surface waters in the watershed, or 25.7 mgd if Worcester's and MWRA's water supplies are excluded. The water need for communities with supplies in the watershed is forecasted to increase to 187 mgd in the year 2020 or 29.7 mgd if Worcester and MWRA water supplies are not included.

Currently, 23.8 mgd of water is distributed in water service areas annually in the basin by the public water suppliers. This amount is forecasted to increase to 28.3 mgd in the year 2020.

The assessment of water conservation by the public water suppliers found room for improvement. Two metrics, residential water use of 80 gpcd or less and unaccounted for water (UAW) of 15 percent or less, were used to evaluate the water conservation programs for each public water supplier. Five out of 25 water suppliers exceeded the residential benchmark of 80 gpcd. Eight water suppliers exceeded the UAW benchmark of 15%. In most cases, the water supplier explained the high UAW in the Annual Statistical Report (ASR) submitted to the Department of Environmental Protection. Additionally, seven public water suppliers reported UAW 5% or less, which is unlikely to be accurate.

ES.4 Water Supplies at Risk

An evaluation was performed to identify public water supplies that are in proximity to either a Massachusetts Contingency Plan (MCP) site or solid waste facility. A ranking system was developed based on the proximity and the risk posed by the site to the water supply. Six community water supplies and three non-community water supplies were considered to be at risk from either a nearby MCP site or a solid waste facility.

ES.5 Wastewater Discharges

Seventeen communities have wastewater collection systems in the watershed. A total of 25.0 mgd of wastewater is collected annually in the watershed. The amount of wastewater collected is forecasted to increase to 32.7 mgd in the year 2020. Currently, four communities export wastewater from the watershed: Ashburnham and Gardner (to Gardner's Wastewater Treatment Plant in the Millers River watershed), and West Boylston, Holden and Rutland (to Worcester's Upper Blackstone wastewater treatment plant).

The Nashua River and its tributaries receive the discharge of wastewater from seven public wastewater treatment plants. Three wastewater treatment plants discharge to the North Nashua River. Wastewater treatment plants also discharge to the main stem of the Nashua River.

The North Nashua River is a good example of the impact of water withdrawal and wastewater discharge. The headwaters of the North Nashua River contain numerous water supply sources, both groundwater and surface water reservoirs. Water is withdrawn from these headwater sources and discharged downstream at the municipal-owned wastewater treatment plants of Fitchburg and Leominster.

ES.6 Inflow/Outflow Analysis

An inflow/outflow analysis for the Nashua River was performed. The watershed was divided into 27 separate subareas, which were used to calculate the water balance at a small scale. This process was performed to determine areas of the watershed that may be subject to diminished river flow, as well as areas that may have the potential for additional withdrawal. The 27 subareas have been grouped into five separate subwatersheds: the Wachusett, North Nashua River, Squannacook River, Nissitissit River, and main Nashua River.

The approach used in the inflow/outflow analysis was to tally the sources and uses of water in each subarea. Information was collected on the location of water supply withdrawals, water distribution and wastewater collection service areas, and areas where wastewater discharge. Annual, August, and winter demand periods were evaluated.

Annual 2000

- The 2000 annual inflow/outflow analysis shows a net gain of 0.7 mgd for the Nashua River watershed or a net loss of 156.5 mgd when MWRA's and Worcester's water withdrawals are included.

- The findings for individual subareas in the watershed are more telling. Of the 27 subareas in the watershed, only eight have a net gain of flow, and 19 subareas have a net loss of flow. Of the eight subareas that gain flow, five of these subareas gain flow from having a wastewater treatment plant discharge in the subarea.

August 2000

- For this scenario, there is a net loss of 1.1 mgd for the Nashua River watershed or a net loss of 165.9 mgd if MWRA's and Worcester's withdrawals are included.

- Water withdrawn in August (29.8 mgd) is 3.5 mgd greater than the average annual volume (26.3 mgd), primarily to meet the greater summer water demand.

- Of the 27 subareas in the watershed, 9 have a net gain of water and 18 have a loss of water.

Annual 2020

- For this scenario, there is a net gain of 0.3 mgd for the Nashua River watershed or a net loss of 157.2 mgd if MWRA's and Worcester's withdrawals are included.

- Water withdrawn (30.0 mgd) predicted in 2020 will increase by 3.7 mgd over the annual amount withdrawn (26.3 mgd) in 2000 primarily to meet the increase in water demand.

- Wastewater collection is forecast to increase from 25.0 mgd in 2000 to 29.9 mgd in 2020, an increase of 4.9 mgd.

- Of the 27 subareas in the watershed, 9 have a net gain of water and 18 have a loss of water.

August 2020

- For this scenario, there is a net loss of 1.9 mgd for the Nashua River watershed or a net loss of 167.4 mgd if MWRA's and Worcester's withdrawals are included.

- Water withdrawals (34.3 mgd) predicted in 2020 will increase by 4.5 mgd over the August 2000 withdrawn amount withdrawn (29.8 mgd) in 2000, primarily to meet the increase in water demand.

- Wastewater collection is expected to increase from 20.3 mgd in 2000 to 24.7 mgd in 2020, an increase of 4.4 mgd.

- Of the 27 subareas in the watershed, 9 have a net gain of water and 18 have a loss of water.

ES.7 Subarea Flow and Stream Flow

The average August and 7Q10 flows, for existing and future scenarios, were compared with predicted virgin flows in order to approximate the level of stress of each subbasin. DEM guidelines, as described in the draft memorandum: *Stressed Basins in Massachusetts* (Office of Water Resources, February 26, 2001) were followed to estimate the stress level of each subbasin.

The DEM has defined three hydrologic stress classifications:

- High-Stress: net outflow equals or exceeds estimated natural August median flow

- Medium-Stress: net outflow equals or exceeds estimated natural 7Q10 flow

- Low-Stress: no net loss to the sub-basin.

Based on these classifications, the stress levels for each subarea were determined for existing conditions (year 2000) as well as predicted conditions in the year 2020. Following the DEM stress classification system,

- One subarea—Flag Brook—is predicted to be highly stressed (net withdrawals exceeding median August flow) in the Nashua River Basin under either existing condition. Additionally, Monoosnoc Brook is predicted to be highly stressed in the future (2020).

- Seven subareas are predicted to have medium stress under existing conditions (net outflow equal/exceeding natural 7Q10): Quinapoxet River 2, Wachusett Reservoir, Monoosnoc Brook, Falulah Brook, Fall Brook, Wekepeke Brook, and Mulpus Brook. In the future (2020), Quinapoxet River 1 and Catacunemaug Brook are expected to be added to the medium stress list.

It is important to note that a large number of the subareas predicted to have some form of stress also contain multi-month reservoirs. These reservoirs are capable of storing large flows in the spring and holding them for use during low flow periods in late summer. Because of the stored volume, the impact of large demands in these basins may not be as great as the stress-classification system implies; it is possible that normal low flows are still being released from these reservoirs. To properly determine the stress levels in these basins, a more detailed study of each subarea is required.

Because the Wachusett watershed is highly managed for the Worcester and MWRA withdrawals, these withdrawals were not considered in the evaluation of stress in the Wachusett Watershed—a much more detailed analysis would be required to evaluate their uses. Instead, the calculations were based on other uses of water in the watershed, particularly withdrawals by Holden, Rutland, Princeton, Sterling, and West Boylston. Based on these withdrawals, three of the four subareas in the Wachusett Watershed were calculated to have medium-stress in the future.

This definition of stress is for water supply purposes. Stress can also be induced on aquatic life from poor water quality, loss of habitat, and for flow reductions less than those defined above.

ES.8 Recommendations

The findings indicate that 11 of the 27 subareas in the Nashua River watershed are or will be either high stressed or medium stressed under the DEM classification system. The stressed subareas are predominately in the Wachusett and North Nashua subwatersheds. The following is recommended for the stressed subareas:

- More detailed inflow/outflow analysis to assess the water balance of the multi-month reservoirs.

- Critical review of any additional water supplies that may be sought in the stressed subareas.

- Emphasis on development and implementation of water conservation plans for communities with supplies in the stressed subareas, especially for those communities that do not meet the benchmark levels.

- Assessment of aquatic habitat impacts from worsening flow stresses.
- Critical review of any additional sewering in the basin, especially sewering that moves water out of a stressed subarea or out of the basin.
- Wastewater reuse or artificial recharge of wastewater discharges should be considered for any WWTP expansion in stressed subareas.

Section 1
Introduction

1.1 General

In 1994, Massachusetts embarked on a different approach for environmental management – the Watershed Initiative. Because the initiative involves the state's coordination of its decision-making process across regulatory programs, the multi-disciplinary Basin Teams were created with the goal of understanding watersheds and the impacts of decisions from the various regulatory programs. This study was prepared for and funded by the Massachusetts Department of Environmental Management (DEM) on behalf of the Nashua River Watershed Team in response to DEM RFR #450, as part of the Massachusetts Watershed Initiative.

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The tasks set forth in this report are similar to the river basin plans historically produced by DEM in conjunction with other state and regional planning agencies. The findings of this report will be used as a basis for water management and wastewater discharge permitting and to assess the potential impacts to biological resources of the watershed that may result from consumptive uses of water.

1.2 Watershed Description

The Nashua River watershed is 538 square miles in area and contains 31 communities. Seven of the communities are in New Hampshire and the remaining 24 communities are in Massachusetts. Figure 1-1 presents the Nashua River watershed. The communities include older, urbanized cities such as Leominster and Fitchburg and smaller, rural towns such as Ashby and Princeton. The population of many of the towns in the watershed is increasing rapidly, with some having growth rates of 20% predicted over the next twenty years.

The headwaters of the Nashua River contain Wachusett Reservoir, a major water supply for the metropolitan Boston area. In addition, the City of Worcester has several reservoirs in the headwaters of the Nashua River, which that city uses as water supply. Worcester's water is distributed and discharged outside of the Nashua River watershed. Overall, 19 communities in the watershed withdraw water either from groundwater wells or from surface water reservoirs for public water supplies. The growth in these communities will put greater demand on the water resources in the Nashua River.

The Nashua River also receives the discharge of wastewater from seven wastewater treatment plants. Two additional communities transfer and discharge wastewater outside the watershed. The North Nashua River is a good example of the impact of water withdrawal and wastewater discharge. The headwaters of the North Nashua River contain numerous water supply sources, both groundwater and surface water. Water is withdrawn from these headwater sources and discharged downstream at the municipally-owned wastewater treatment plants of Fitchburg and Leominster.

The development of the relationship of water withdrawal and wastewater discharge and their effect on river flow is the main objective for this study. In addition, this report examines the effects of future population growth and the associated demand for additional water supply sources and increase in wastewater flow.

1.3 Overview of Assessment

The steps in the hydrologic assessment include:

Collect Background Information: Collect information on water supply, stream flow, water supply needs assessments, population growth projections, aquifers, and watershed protection areas, Water Management Act approvals, and wastewater disposal.

Evaluate Potential Impacts: This work includes estimating the future water supply needs for the communities and determining the water supplies at risk from nearby MCP and Solid Waste Sites.

Conduct Inflow / Outflow analysis: Assess the inflow and outflow of water from each subarea under current and future water use conditions.

Estimate the Virgin Flow or Yield for each Subarea: Using USGS stream flow data and other information, estimate the virgin flow or yield from each subarea.

Assess Changes in Subarea Yield and Stream Flow: Coupling the inflow / outflow analysis with the stream flow information, assess the impacts on subarea yields and stream flows.

Apply State Criteria for Minimum Stream Flow: Apply the state criteria for stressed basins for each stream segment to identify flow-stressed streams.

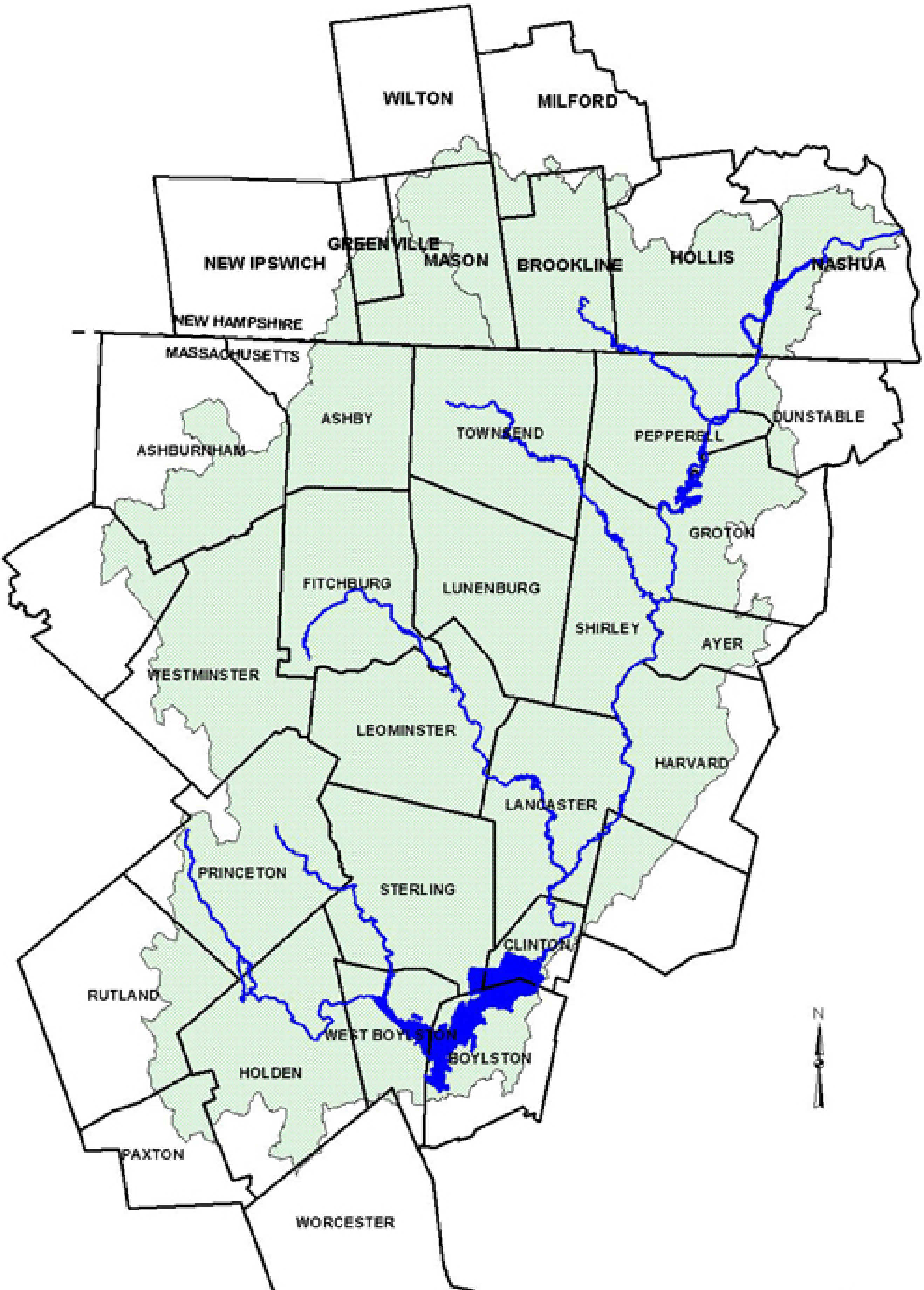

Figure 1-1
Nashua River Watershed

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Section 2
Background Information

2.1 General

This section presents data collected for the Hydrologic Assessment of the Nashua River Watershed. Data are summarized in tables and figures that accompany the text descriptions provided below (Note: all tables and figures follow the text). The text descriptions include information on data sources, period of record, measurement frequency, assumptions made, and additional data needs for the following data categories:

- Community Land Areas in the Basin
- Surficial Geology and Aquifer Delineations
- Water Supplies
- Water and Wastewater Discharges
- Population
- USGS Streamflow Data

2.2 Community Land Areas

Table 2-1 presents a list of the 24 Massachusetts communities in the Nashua River Watershed and the percent of their land that is within the watershed boundaries. The total land area for each community is also shown.

2.3 Surficial Geology and Aquifer Delineations

Figure 2-1 presents the surficial geological features of the Nashua River Watershed, as obtained from MassGIS. As can be seen from the figure, the basin is dominated by till or bedrock with lesser areas of sand and gravel deposits. There is also floodplain alluvium near the river and the major tributaries. Sand and gravel deposits are generally indicative of potential aquifer areas, though actual aquifers will generally be much more limited than the sand and gravel deposits indicate.

Approximate aquifer delineations, obtained from USGS Report 88-4147: *Stream-Aquifer Relations and Yield of Stratified-Drift Aquifers in the Nashua River Basin, Massachusetts* (1991), are also presented in Figure 2-1. These areas were digitized on-screen by comparing GIS features with features in the location map of the USGS Report, so they are for reference only, and they are not appropriate for use in any detailed aquifer survey. Six aquifers were studied in the USGS report: Pearl Hill-Willard Brooks, Witch Brook, Catacunemaug Brook, Wekepeke Brook, Still River, and Stillwater River.

Table 2-1
Communities in Nashua River Basin

Community	Total Land Area (mi^2)	Land Area in Nashua River Basin (mi^2)	Percent of Land in Nashua River Basin
Ashburnham	41	16	40%
Ashby	24	20	82%
Ayer	10	7.9	83%
Bolton	20	5.7	28%
Boylston	20	11	56%
Clinton	7.3	6.2	85%
Dunstable	17	3.4	20%
Fitchburg	28	28	100%
Gardner	23	4.6	20%
Groton	34	21	63%
Harvard	27	17	63%
Holden	36	30	82%
Lancaster	28	28	100%
Leominster	30	30	100%
Lunenburg	28	28	100%
Paxton	15	3.0	19%
Pepperell	23	23	100%
Princeton	36	31	86%
Rutland	36	8.5	23%
Shirley	16	16	100%
Sterling	32	32	100%
Townsend	33	33	100%
West Boylston	14	13	92%
Westminster	37	30	81%
Worcester	38	0.3	1%

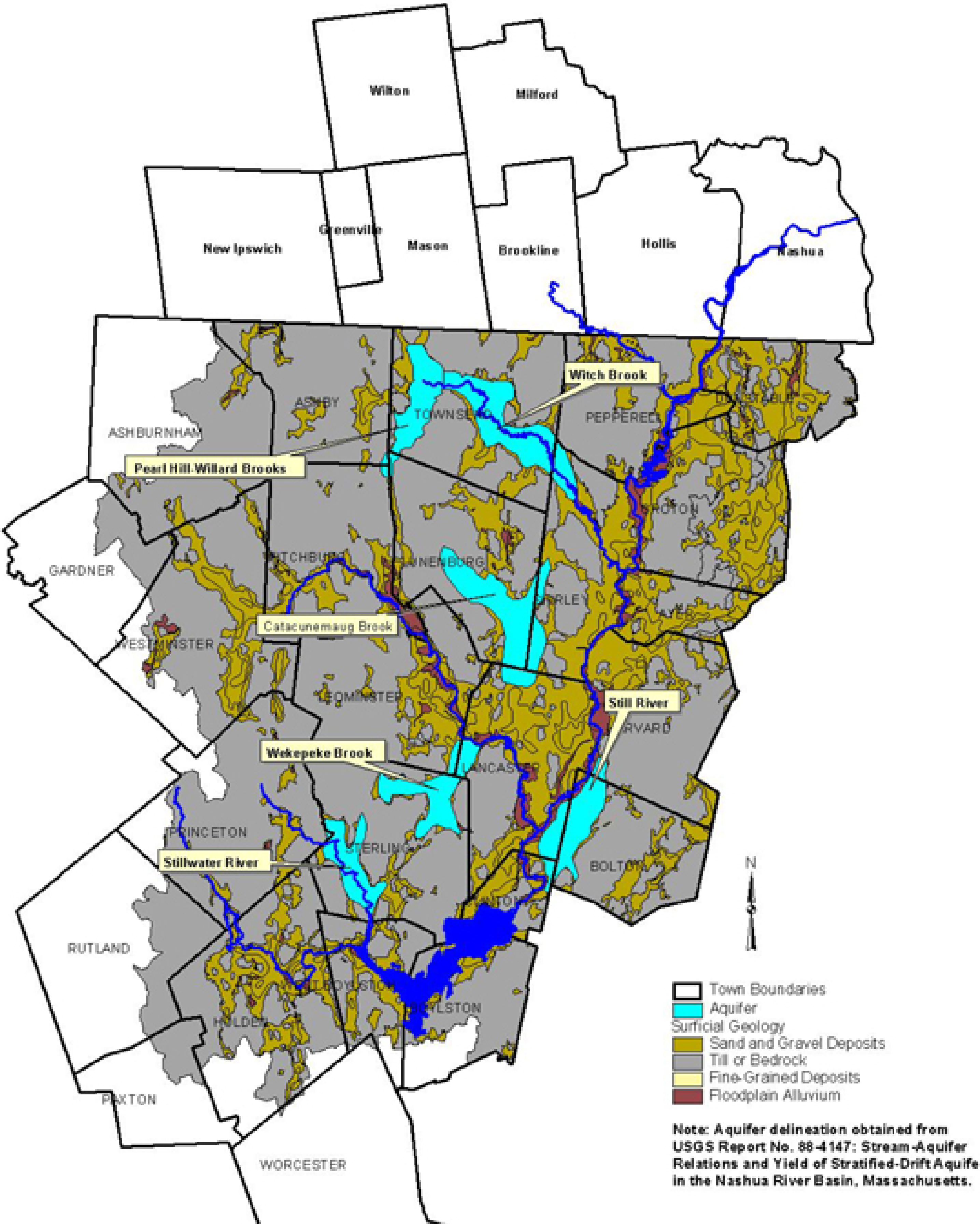

Figure 2-1
Surficial Geology and Aquifer Delineation
Nashua River Watershed

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2.4 Water Supplies

Tables 2-2 through 2-6 present summary information on public water supplies and private (i.e., non-community) water supplies in the basin. Data presented in these tables were obtained from the following sources:

- ***Annual Statistical Reports (ASR) from 1994 through 1998.*** These reports are required for all Public Water Supply sources that withdraw more than 100,000 gallons per day (gpd). The ASR typically includes the following information: monthly withdrawal volumes by source and an annual total; information on water bought and sold to other public water suppliers; estimates of water allocation by sector; source location; source type (i.e., groundwater or surface water); and may include information on water conservation programs. These data are summarized in Tables 2-2 through 2-6. Figure 2-2 presents the average demand, including industrial withdrawals, in the Nashua River Watershed from 1994-1998, based on the available ASR data. This figure indicates an unusual increase in flow in November; this increase was verified as coming from Fitchburg, and it may be the result of snow making activities for ski slopes. Figures 2-3 through 2-25 present the average monthly demand for each community where monthly data were available and reasonably complete, based on available ASR data. Figure 2-26 presents the water allocation by sector for Leominster, and Figure 2-27 presents the water allocation by sector for Pepperell. These communities were selected because they are reasonably representative of the larger, more commercial towns (Leominster) and the smaller, more residential towns (Pepperell).

  Table 2-2 presents water bought and sold. Six communities sell water—of these, three involve an interbasin transfer. Seven communities buy water- all water bought is from within the Nashua Basin. Table 2-3 includes average annual withdrawals for public water suppliers, obtained by averaging available ASR data from 1994-1998. Public and industrial water suppliers reported a cumulative average annual withdrawal of approximately 45.5 mgd from 1994-1998. Table 2-4 provides summary information on the number, type, name and location of public water supplies in the Nashua Basin. An estimate of the population served by public water supply is also included. Table 2-5 presents allocations of public water supply use by sector as reported in the 1998 ASR. Table 2-6 shows total annual withdrawals from the 1998 ASR for private water suppliers. Private water suppliers reported a cumulative annual withdrawal of 7.52 mgd for 1998.

- ***Registration Statements for Water Withdrawal.*** Public and Private Water Supplies that withdraw more than 100,000 gpd were required to register their average annual withdrawal volume for 1981-85 with the Department of Environmental Protection (DEP) following passage of the Water Management Act in 1986. These volumes are essentially considered "grandfathered". There are 44 Registered users in the Nashua River Watershed and their total registered volume is 174 million gallons per day (mgd). Of this, 126 mgd is from the MWRA and 48 mgd is from other users. Of the 48 mgd, roughly, 31 mgd is public water supplies,

Table 2-2
Presence and allocation of Public Water Supplies in Nashua River Basin Communities

MUNICIPALITIES/ WATER SUPPLIER	Presence of PWS[1]	Public Water Supply Source Basin	Water Supply Source Subbasins	Bought or Transfered From[2]		Sold or Transferred To[2]	
				Community	Basin	Community	Basin
ASHBURNHAM	PWS	MILLERS	sources outside the basin				
ASHBY	*all PRIVATE*	NASHUA	private, no information				
AYER	PWS	NASHUA	Bower Brook and Nashua River Mainstem 3	Occasionally Devens	Nashua	Occasionally Devens	Nashua
BOLTON	*all PRIVATE*	NASHUA/CONCORD	private, no information				
BOYLSTON	PWS	NASHUA/BLACKSTONE	Wachusett Reservoir and sources outside the basin				
CLINTON	PWS	NASHUA/QUABBIN	Wachusett Reservoir, Nashua River Mainstem 4, Wekepeke Brook				
DEVENS	PWS	NASHUA	Bower Brook	Occasionally Ayer	Nashua	Occasionally Ayer	Nashua
DUNSTABLE	PWS	MERRIMACK	sources outside the basin				
FITCHBURG	PWS	NASHUA	Squannacook River 3, Falulah Brook, North Nashua River 3, Flag Brook	-	-	Westminster	Nashua
GARDNER	PWS	MILLERS	sources outside the basin				
GROTON	PWS	NASHUA/MERRIMACK	Squannacook River 1 and sources outside the basin				
HARVARD	PWS	NASHUA	Bower Brook and Nashua River Mainstem 3				
HOLDEN	PWS	NASHUA/BLACKSTONE	Quinapoxet River 1 and 2, and sources outside the basin	Worcester	Nashua	Worcester	Blackstone
LANCASTER	PWS	NASHUA	Nashua River Mainstem 3 and 4, North Nashua River 1				
LEOMINSTER	PWS	NASHUA	Fall Brook, Monoosnoc Brook, Wekepeke Brook, Wachusett Reservoir				
LUNENBURG	PWS	NASHUA	Mulpus Brook, Catacunemaug Brook				
MWRA	PWS	QUABBIN/WARE/NASHUA	Quinapoxet River 1 and 2, and Wachusett Reservoir			Greater Boston	Various Basins
PAXTON	PWS	NASHUA	Quinapoxet River 1	Worcester	Nashua	-	-
PEPPERELL	PWS	NASHUA	Nissitissit River, Nashua River Mainstem 2				
PRINCETON	*all PRIVATE*	NASHUA/CHICOPEE	private, no information				
RUTLAND	PWS	NASHUA/CHICOPEE	Quinapoxet River 2 and sources outside the basin				
SHIRLEY	PWS	NASHUA	Nashua River Mainstem 2 and 3	Devens?	Nashua	-	-
STERLING	PWS	NASHUA	Stillwater River				
TOWNSEND	PWS	NASHUA	Squannacook River 1 and 2				
WEST BOYLSTON	PWS	NASHUA	Wachusett Reservoir				
WESTMINSTER	PWS	NASHUA/CHICOPEE	Flag Brook and sources outside the basin	Fitchburg	Nashua	-	-
WORCESTER	PWS	NASHUA/ BLACKSTONE	Quinapoxet River 1 and 2	Holden	Nashua	multiple communities	Nashua Blackstone

Notes:
[1] PWS= public water supply (i.e., central distribution), may also have private wells
[2] Data are from Annual Statistical Reports

Table 2-3
Summary of Registered, Permitted and Historical Water Supply Volumes for Public Water Suppliers in the Nashua River Basin

Public Water Supply (PWS)	Community	Registered Amount[1] MGD	Permitted to 2/1999[1] MGD	Permitted to 2/2004[1] MGD	Permitted to 2/2009[1] MGD	Permitted to 2/2014[1] MGD	Average Annual Demand[2] MGD	Years of ASR Data
Ayer Water Dept.	Ayer	0.82	0.79	1.00	1.18	1.18	1.22	5
Boylston Water Dept.	Boylston	0.19	0.10	0.10	0.10	0.11	0.39	3 Years, 95-97
Morningdale Water Dist.	Boylston	0.17	NP	NP	NP	NP	0.39	3 Years, 95-97
Clinton Water Dept.	Clinton	NR	NP[3]	NP	NP	NP	2.10	5
Devens Water System	Devens	1.35	2.95	2.95	3.25	3.45	0.48	5
Dunstable Water Dept	Dunstable	NR	NP[4]	NP	NP	NP	0.06	1 Year, 1998
Fitchburg Water Department	Fitchburg	6.19	NP[4]	NP	NP	NP	7.37	5
Gardner DPW	Gardner	1.69	NP[5]	NP	NP	NP	2.10	5
Groton Water Dept.	Groton	0.22	0.23	0.28	0.30	0.33	0.36	5
Harvard Water Supply	Harvard	NR	NP[4]	NP	NP	NP	0.02	1 Year, 1998
Town of Holden	Holden	1.15	0.11	NP[5]	NP	NP	1.45	5
Lancaster DPW	Lancaster	0.53	NP[4]	NP	NP	NP	0.55	2 Years, 94,98
City of Leominster	Leominster	4.94	NP[4]	NP	NP	NP	6.67	4 Years, 94-97
Lunenburg Water District	Lunenburg	0.29	0.15	0.19	0.22	0.25	0.46	5
Paxton Water Dept.	Paxton	0.27	NP[4]	NP	NP	NP	0.16	2 Years, 95,98
Pepperell Water	Pepperell	0.74	NP	0.47	0.51	0.56	2.16	5
Town of Rutland	Rutland	0.26	0.10	0.10	0.10	0.11	0.29	5
MCI Shirley	Shirley	NR	NP[5]	NP	NP	NP	0.59	5
Shirley Water District	Shirley	NR	0.29	0.30	0.31	0.31	0.59	5
Sterling Water Dept.	Sterling	0.40	0.14	0.17	0.20	0.23	0.47	5
Townsend Water Dept	Townsend	0.50	NP[4]	NP	NP	NP	0.59	5
Witches Brook	Townsend	0.26	NP[4]	NP	NP	NP	0.59	5
West Boylston Water District	West Boylston	0.56	NP	NP	NP	NP	0.65	5
West Groton Water Supply	West Groton	0.27	NP[4]	NP	NP	NP	0.26	5
Westminster Water Dept.	Westminster	0.24	0.22	0.25	0.28	0.32	0.00	1 Year, 1998
Worcester DPW	Worcester	24.07	NP[5]	NP	NP	NP	8.01[8]	5
MWRA	Boston Metro Area	126.12[6]	NP	NP	NP	NP	148	5
Totals		45.10[7]	5.08	5.81	6.45	6.85	37.99[7]	
Cumulative Total			50.18[7]	50.91[7]	51.55[7]	51.95[7]		

Notes:
1 From Duane LeVangie (DEP) 8/99, 2/00 and DEP CERO files. Note: permitted amount is in addition to registered amount.
2 Amounts are from 1994-1998 Annual Statistical Report (ASR) or most recent years available (noted in adjacent column)
3 Special Arrangement, water provided by MWRA
4 No permit required because total withdrawals are either under the Water Management Act threshold of 100,000 gallons per day (gpd) or less than 100,000 gpd over the registered amount.
5 Water Management Act permit is currently under review
6 MWRA's total registered volume is 312.9 MGD (including Quabbin). Their registration allows them to take a maximum of 178 MGD annually from Wachusett.
7 Does not include MWRA
8 Annual Average flow for Worcester is only the portion supplied from the Nashua River Watershed
NR = Not Registered
NP = Not Permitted
MGD = millions of gallons per day

Table 2-4
Summary information on number, type, name and location of Public Water Supply sources in the Nashua River Basin

Community	Public Water Supply (PWS) Name	Estimated % Population Served[1]	Source Type and Number of Sources		Source Location and Notes[2]
			Groundwater	Surface Water	
Ayer	Ayer Water Dept.	100%	7, 5 in basin	0	Grove Pond wells, Patton well, Shabokin Rd.well, Mcpherson well
Boylston	Boylston Water Dept.	no information	5, 1 in basin	0	Rt. 70 and 140, and Scar Hill Bluffs wells
Boylston	Morningdale Water Dist.	37%	Interconnected to Boylston		Rt. 70 and 140 wells
Clinton	Clinton Water Dept.	92%	0	3	Wachusett Reservoir, Heywood Reservoir, Wekepeke Reservoir
Devens	Devens Water System	no information	4	1	Grove Pond, unnamed wells
Dunstable	Dunstable Water Dept	no information	2, 0 in basin	0	GP Well 2, Tub Well, Pleasant St.
Fitchburg	Fitchburg Water Department	100%	0	10, 9 in basin	Mare Meadow, Meetinghouse, Bickford, and Wyman's Ponds; Wachusetts Lake; Overlook, Scott, Faluhah, Lovell, and Shattuck Reservoirs.
Gardner	Gardner DPW	97%	0	3, 0 in basin	Crystal Lake, Perley Brook and Cowes Pond
Groton	Groton Water Dept.	100%	4, 1 in basin	0	Baddacook and Whitney wells
Harvard	Harvard Water Supply	8%	3	0	Well #2, Bare Hill Pond Rd., Bolton Rd. 2
Holden	Town of Holden	89%	4	1	Muschopauge Pond; Spring St., Quinapoxet, Mill St., and Mason Rd. wells
Lancaster	Lancaster DPW	23%	4	0	unnamed wells, MCI Shirley wells 1 and 2
Leominster	City of Leominster	89%	4	8	Goodfellow and Rocky Ponds; Simmons Pond, No-Town, Haynes, and Fall Brook Reservoirs; and Southeast wells 1-3 and Wass Meadow well
Lunenburg	Lunenburg Water District	67%	5	0	Lancaster Ave unnamed wells, Hickory Hills well
Paxton	Paxton Water Dept.	83%	0	1	Asnebumskit Pond
Pepperell	Pepperell Water	61%	2	0	Jersey St. and Bemis wells
Rutland	Town of Rutland	59%	0	1	Muschopauge Pond
Shirley	Shirley Water District	54%	3	0	Catacunemaug, Patterson and Samson wells
Sterling	Sterling Water Dept.	72%	5	0	Rt. 12 Worcester Rd. wells
Townsend	Townsend Water Dept	47%	9	0	Main St. and GP wells, Witches Brook wells 1 and 2.
West Boylston	West Boylston Water District	91%	5	1	Lee St., Oakdale and Pleasant Valley wells, Wachusett Reservoir
West Groton	West Groton Water Supply	no information	1	0	Townsend Rd. well
Westminster	Westminster Water Dept.	77%	0	1	Meetinghouse Pond
Worcester	Worcester DPW	100%	1, 0 in basin	6, 4 in basin	Holden 1&2, Kendall, Quinapoxet and Lynde Brook Reservoirs; Coal Mine and Shrewsbury wells
Boston	MWRA	100%	0	1	Wachusett Reservoir

Notes:
[1] Estimate based on "population served" reported in Annual Statistical Reports and 1995 Estimated Population data from the 1990 Census.
[2] From Annual Statistical Reports

Table 2-5
Allocation of Public Water Supply use by sector in the Nashua River Basin

Community	Public Water Supply (PWS)	Percent Allocation by Sector				
		Residential	Commercial	Industrial	Other	Unaccounted
Ayer	Ayer Water Dept.	40%	40%	0%	10%	10%
Boylston[2]	Boylston Water Dept.	36%	34%	0%	20%	10%
Boylston[2]	Morningdale Water Dist.	47%	2%	0%	3%	48%
Clinton	Clinton Water Dept.	68%	6%	23%	3%	1%
Devens	Devens Water System	13%	68%	3%	16%	0%
Dunstable	Dunstable Water Dept	No Info.	No Info.	No Info.	No Info.	No Info.
Fitchburg	Fitchburg Water Department	35%	7%	12%	27%	19%
Gardner	Gardner DPW	46%	6%	4%	11%	33%
Groton	Groton Water Dept.	87%	6%	0%	7%	0%
Harvard	Harvard Water Supply	54%	10%	0%	27%	10%
Holden	Town of Holden	lumped	lumped	lumped	2%	30%
Lancaster	Lancaster DPW	No Info.	No Info.	No Info.	No Info.	No Info.
Leominster[2]	City of Leominster	50%	24%	14%	3%	9%
Lunenburg	Lunenburg Water District	74%	3%	0%	10%	13%
Paxton	Paxton Water Dept.	97%	2%	0%	2%	0%
Pepperell	Pepperell Water	75%	5%	4%	6%	8%
Rutland	Town of Rutland	81%	0%	0%	8%	11%
Shirley	MCI Shirley	No Info.	No Info.	No Info.	No Info.	No Info.
Shirley	Shirley Water District	87%	3%	2%	2%	6%
Sterling	Sterling Water Dept.	65%	5%	3%	10%	17%
Townsend	Townsend Water Dept	52%	19%	5%	3%	21%
Townsend	Witches Brook	100%	0%	0%	0%	0%
West Boylston	West Boylston Water District	56%	8%	0%	3%	33%
West Groton	West Groton Water Supply	50%	40%	0%	8%	2%
Westminster	Westminster Water Dept.	91%	6%	1%	2%	0%
Worcester	Worcester DPW	29%	49% lump?	0%	6%	16%
	Range:	13 - 100%	0 - 68%	0 - 23%	0 - 27%	0 - 48%

Notes:
Shaded cells are calculated based on number of connections
[1] Data are from 1994 - 1998 Annual Statistical Reports (ASR)
[2] Data are from 1997 ASR
[3] Category "Other" includes agricultural, municipal, other, and process water uses.

Table 2-6
Summary of Registered, Permitted and Historical Water Supply Volumes for Non Community Water Supplies in the Nashua River Watershed

Non Community Water Supply	Community	Registered Amount[1] MGD	Permitted to 2/2004[1] MGD	Permitted to 2/2009[1] MGD	Permitted to 2/2014[1] MGD	Average Annual ASR Total[2] MGD	Years of ASR Data
Hollingsworth & Vose Co.	West Groton	2.42	NP	NP	NP	2.36	5
Munksjo Paper Decor, Inc.	Fitchburg	NR	1.23	1.13	1.08	1.10	5
Pepperell Paper Co.	Pepperell	1.50	NP	NP	NP	1.07	5
Intercontinental Recycling Corp.	Fitchburg	5.20	NP	NP	NP	1.22	5
Custom Papers Group, Inc.	Fitchburg	1.06	NP	NP	NP	0.89	3 Years, 95,96,98
Simmonds Cutting Tools	Fitchburg	0.26	NP	NP	NP	0.28	5
Epic Enterprises, Inc.	Ayer	NR	NP[3]	NP	NP	0.23	3 Years 96-98
R.J. Paquette	Holden	0.30	NP	NP	NP	0.13	5
The International	Bolton	0.12	NP	NP	NP	0.16	4 Years, 95-98
Busy Bee Nursery	Holden	0.13	NP	NP	NP	0.08	5
Totals		10.99	1.23	1.13	1.08	7.52	
Cumulative Total			12.22	12.12	12.07		

Notes:
[1] From Duane LeVangie (DEP) 8/99 and DEP CERO files
[2] Amounts are from 1998 Annual Statistical Report (ASR)
[3] Permit was denied. Thought to be purchasing water from Ayer (LeVangie, pers. comm. 2/00)
NR = Not Registered
NP= No permit required because total withdrawals are less than 100,000 gallons per day over the registered amount.

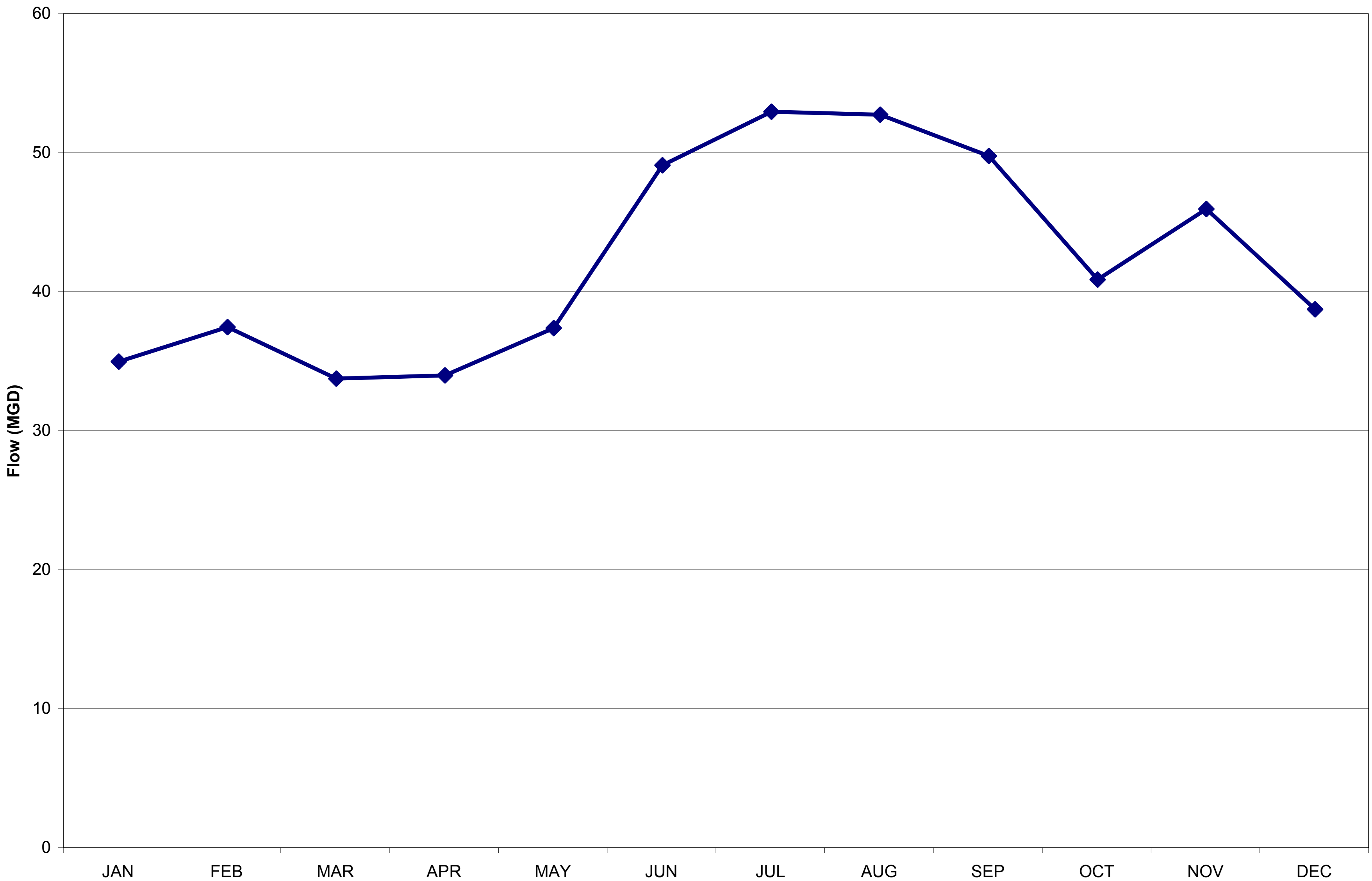
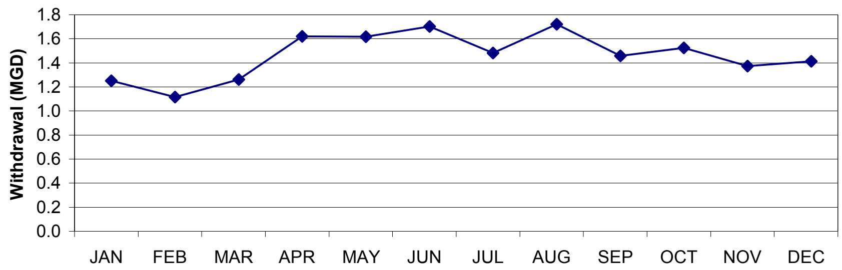
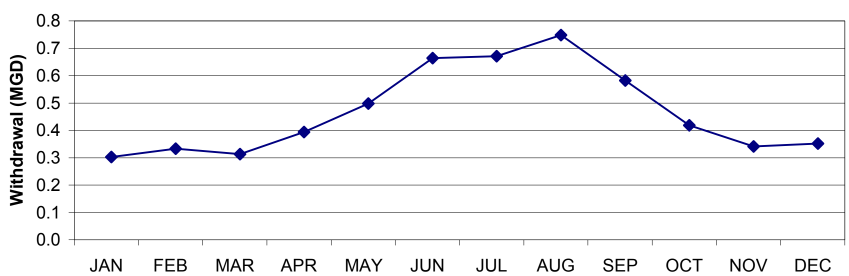


Figure 2-2
Average (1994-1998) Monthly Water Withdrawal of Towns in the Nashua River Watershed



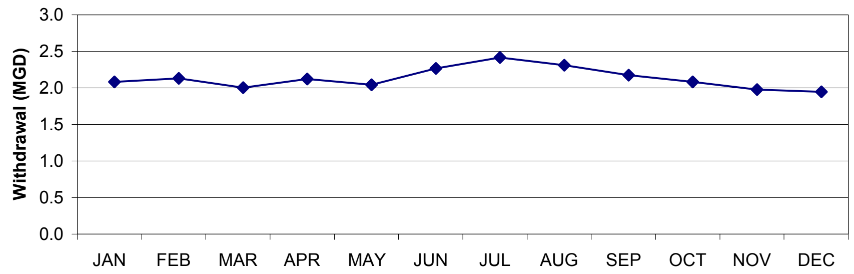
PWS Name	Town	PWS ID	Average Withdrawal (mgd)	Pattern Data
Epic Enterprises, Inc.	Ayer	2019005	0.23	NO
Ayer Water Dept.	Ayer	2019000-01G	0.09	YES
Ayer Water Dept.	Ayer	2019000-02G	0.04	YES
Ayer Water Dept.	Ayer	2019000-04G	0.49	YES
Ayer Water Dept.	Ayer	2019000-03G	0.59	YES
Littleton Lyne Apts	Ayer	2019007	0.01	NO
Total			**1.45**	

Figure 2-3
Monthly Water Use Pattern, 1994-1998
Ayer



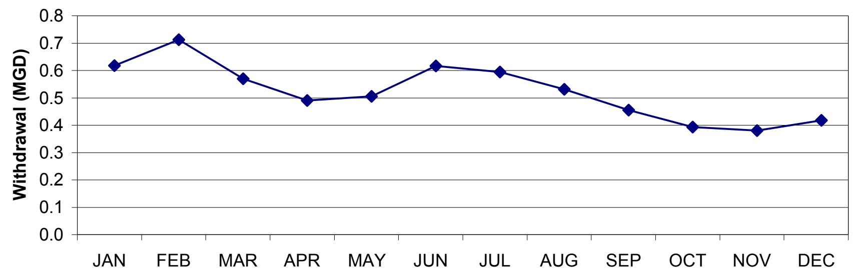
PWS Name	Town	PWS ID	Average Withdrawal (mgd)	Pattern Data
Florence Sawyer School	Bolton	2034024-01G	0.0004	YES
Boylston Water Dept.	Boylston	203900-01G	0.0	NO
Boylston Water Dept.	Boylston	203900-02G	0.26	YES
Boylston Water Dept.	Boylston	203900-03G	0.0	NO
Morningdale Water Dist.	Boylston	2039001-01G	0.14	YES
Morningdale Water Dist.	Boylston	2039001-02G	0.0	NO
Mt. Pleasant Country Club	Boylston		0.02	YES
Total			**0.42**	

Figure 2-4
Monthly Water Use Pattern, 1994-1998
Boylston



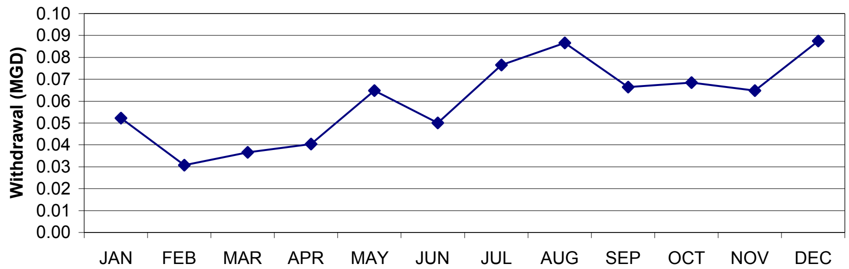
PWS Name	Town	PWS ID	Average Withdrawal (mgd)	Pattern Data
Clinton Water Dept.	Clinton	2064000-01P	2.10	YES
Total			**2.10**	

Figure 2-5
Monthly Water Use Pattern, 1994-1998
Clinton



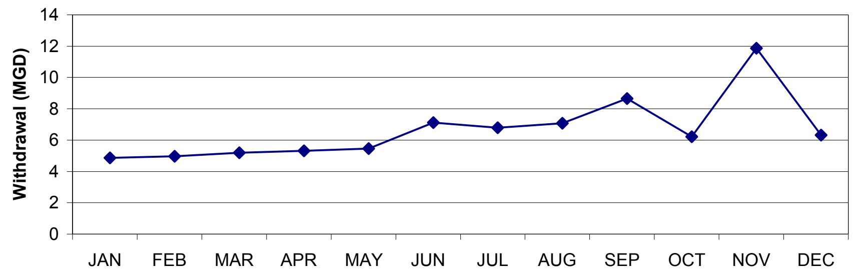
PWS Name	Town	PWS ID	Average Withdrawal (mgd)	Pattern Data
Devens Water System	Devens	2019001-1501	0.06	YES
Devens Water System	Devens	2019001-1502	0.07	YES
Devens Water System	Devens	2019001-1503	0.16	YES
Devens Water System	Devens	2019001-1504	0.19	YES
Devens Water System	Devens		0.0	NO
Total			**0.48**	

Figure 2-6
Monthly Water Use Pattern, 1994-1998
Devens



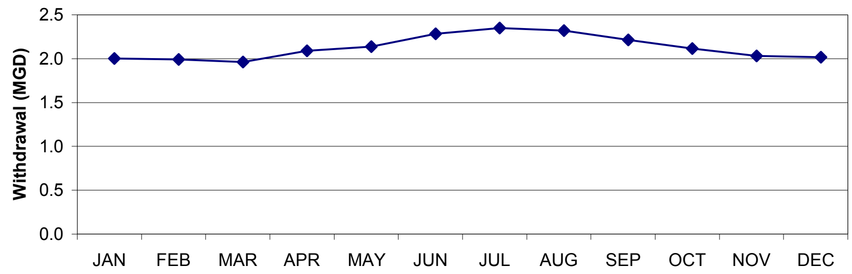
PWS Name	Town	PWS ID	Average Withdrawal (mgd)	Pattern Data
Dunstable Water Dept	Dunstable	2081000-02G	0.06	YES
Total			**0.06**	

Figure 2-7
Monthly Water Use Pattern, 1998
Dunstable



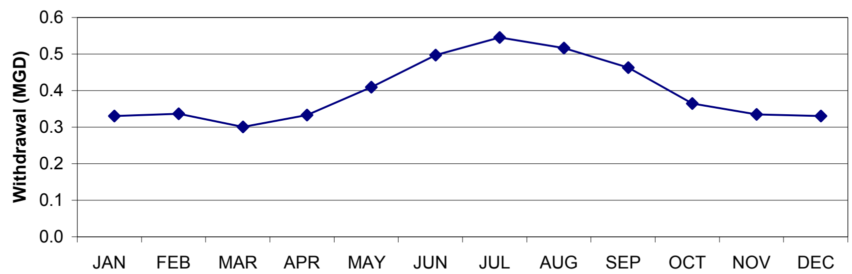
PWS Name	Town	PWS ID	Average Withdrawal (mgd)	Pattern Data
Fitchburg Water Department	Fitchburg	2097000-07S	0.40	YES
Fitchburg Water Department	Fitchburg	2097000-02S	0.18	YES
Fitchburg Water Department	Fitchburg	2097000-05S	1.39	YES
Fitchburg Water Department	Fitchburg	2097000-04S	0.0	NO
Fitchburg Water Department	Fitchburg	2097000-09S	0.23	YES
Fitchburg Water Department	Fitchburg	2097000-06S	0.80	YES
Fitchburg Water Department	Fitchburg	2097000-13S	0.0	NO
Fitchburg Water Department	Fitchburg	2097000-10S	0.0	NO
Intercontinental Recycling Corp.	Fitchburg		0.45	YES
Intercontinental Recycling Corp.	Fitchburg		0.09	YES
Intercontinental Recycling Corp.	Fitchburg		0.68	YES
Custom Papers Group, Inc.	Fitchburg		0.89	YES
Oak Hill Country Club	Fitchburg		0.03	YES
Simmonds Cutting tools	Fitchburg		0.04	YES
Simmonds Cutting tools	Fitchburg		0.0	NO
Simmonds Cutting tools	Fitchburg		0.01	YES
Simmonds Cutting tools	Fitchburg		0.0	NO
Simmonds Cutting tools	Fitchburg		0.07	YES
Simmonds Cutting tools	Fitchburg		0.08	YES
Simmonds Cutting tools	Fitchburg		0.07	YES
Simmonds Cutting tools	Fitchburg		0.02	YES
Munksjo Paper Decor, Inc.	Fitchburg		1.10	YES
Total			**6.52**	

Figure 2-8
Monthly Water Use Pattern, 1997-1998
Fitchburg



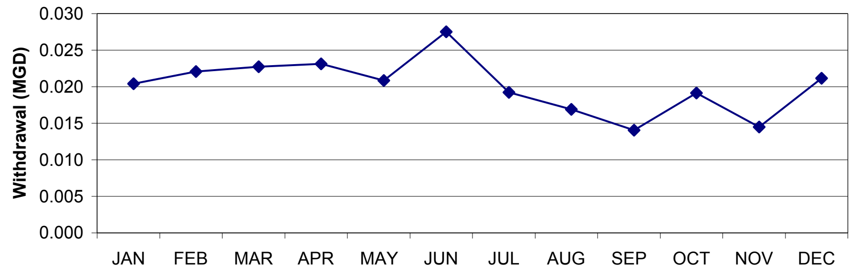
PWS Name	Town	PWS ID	Average Withdrawal (mgd)	Pattern Data
Gardner DPW	Gardner	2103000-01S	2.10	YES
Total			**2.10**	

Figure 2-9
Monthly Water Use Pattern, 1994-1998
Gardner



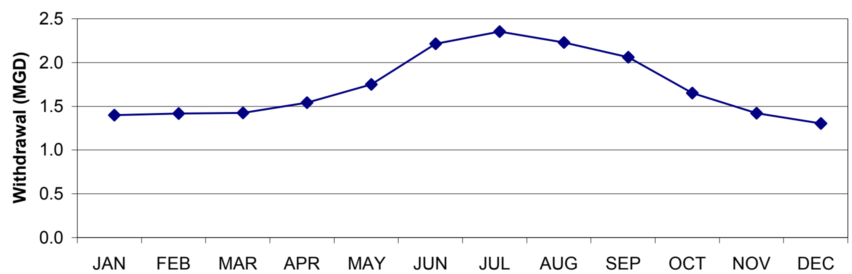
PWS Name	Town	PWS ID	Average Withdrawal (mgd)	Pattern Data
Groton Water Dept.	Groton	2115000-02G	0.04	YES
Groton Water Dept.	Groton	2115000-03G	0.32	YES
Total			**0.36**	

Figure 2-10
Monthly Water Use Pattern, 1994-1998
Groton



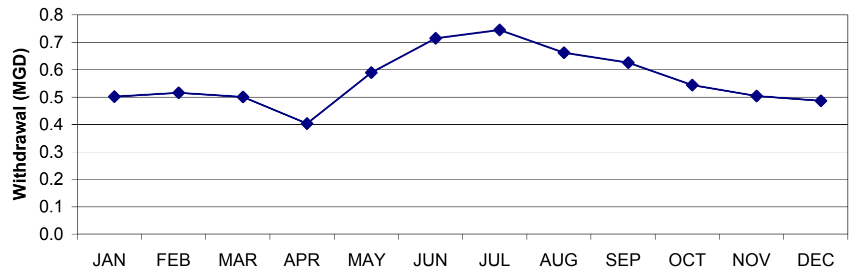
PWS Name	Town	PWS ID	Average Withdrawal (mgd)	Pattern Data
Harvard Water Supply	Harvard	2125000	0.017	YES
Village Nusery School	Harvard	2125005	0.0002	YES
Harvard Green Condo	Harvard	2125014-01G	0.0006	YES
Harvard Green Condo	Harvard	2125014-02G	0.0007	YES
Gaia Herbs/Hillside Medical	Harvard	2125012	0.0	NO
Foxglove Apts.	Harvard	2125013	0.001	YES
Total			**0.02**	

Figure 2-11
Monthly Water Use Pattern, 1998
Harvard



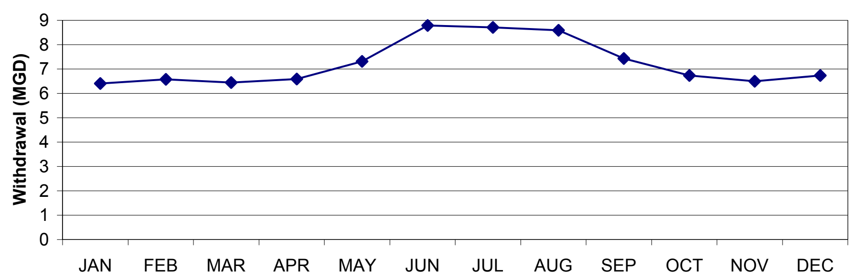
PWS Name	Town	PWS ID	Average Withdrawal (mgd)	Pattern Data
Town of Holden	Holden	2134000-01S	0.37	YES
Town of Holden	Holden	2134000-01G	0.15	YES
Town of Holden	Holden	2134000-02G	0.50	YES
Town of Holden	Holden	2134000-03G	0.24	YES
Town of Holden	Holden	2134000-04G	0.12	YES
Reed Plastics Corp.	Holden		0.0	NO
R.J. Paquette	Holden		0.12	YES
R.J. Paquette	Holden		0.01	YES
Busy Bee Nursery	Holden		0.08	YES
Holden Country Club	Holden		0.0	NO
Holden Sand and Gravel Co.	Holden		0.01	YES
Lancaster DPW	lancaster	2147000-01G	0.25	YES
Lancaster DPW	lancaster	2147000-02G	0.30	YES
Total			**2.14**	

Figure 2-12
Monthly Water Use Pattern, 1994-1998
Holden



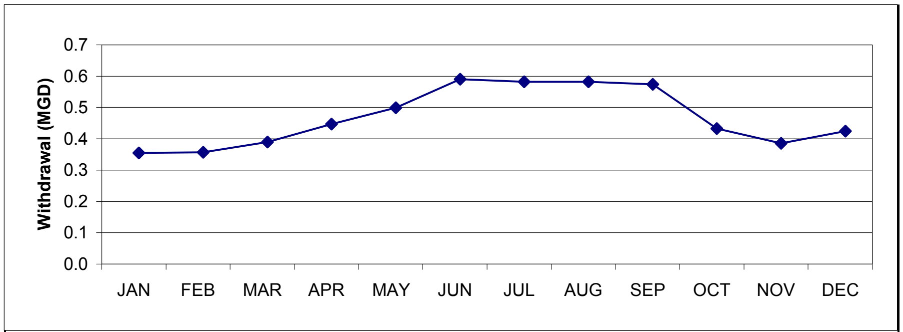
PWS Name	Town	PWS ID	Average Withdrawal (mgd)	Pattern Data
Lancaster DPW	lancaster	2147000-01G	0.25	YES
Lancaster DPW	lancaster	2147000-02G	0.30	YES
Lancaster Golf	lancaster	2147004-01G	0.001	NO
The Rockport Co	lancaster	2147005	0.003	YES
Total			**0.56**	

Figure 2-13
Monthly Water Use Pattern, 1994-1998
Lancaster



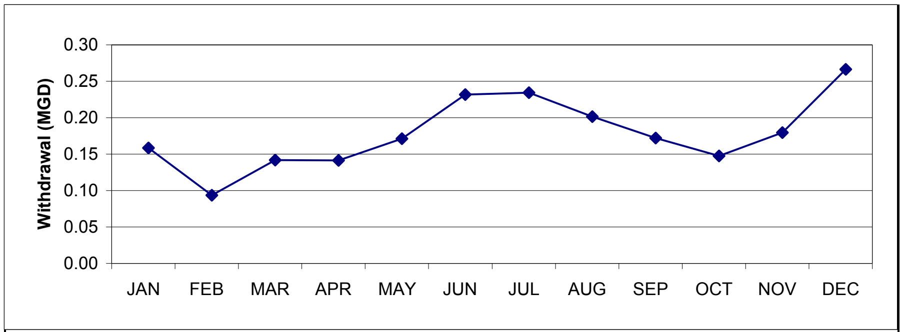
PWS Name	Town	PWS ID	Average Withdrawal (mgd)	Pattern Data
City of Leominster	Leominster	2153000-01G	0.0	NO
City of Leominster	Leominster	2153000-01S	1.06	YES
City of Leominster	Leominster	2153000-05G	0.0	NO
City of Leominster	Leominster	2153000-04G	0.21	YES
City of Leominster	Leominster	2153000-03G	0.30	YES
City of Leominster	Leominster	2153000-06S	0.0	NO
City of Leominster	Leominster	2153000-09S	1.73	YES
City of Leominster	Leominster	2153000-02S	0.0	NO
City of Leominster	Leominster	2153000-05S	1.45	YES
City of Leominster	Leominster	2153000-03S	1.06	YES
City of Leominster	Leominster	2153000-07S	0.84	YES
Gove Farm	Leominster		0.01	YES
The BFGoodrich Company	Leominster		0.04	YES
Total			**6.71**	

Figure 2-14
Monthly Water Use Pattern, 1994-1998
Leominster



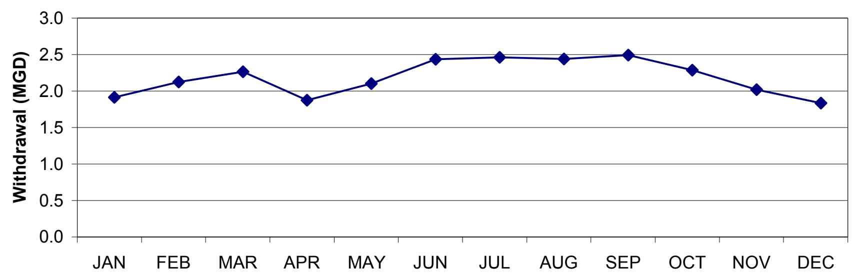
PWS Name	Town	PWS ID	Average Withdrawal (mgd)	Pattern Data
Lununburg Water District	Lunenburg	2162000-01G	0.09	YES
Lununburg Water District	Lunenburg	2162000-02G	0.05	YES
Lununburg Water District	Lunenburg	2162000-04G	0.11	YES
Lununburg Water District	Lunenburg	2162000-03G	0.0	NO
Lununburg Water District	Lunenburg	2162000-05G	0.12	YES
Lununburg Water District	Lunenburg	2162000-06G	0.10	YES
Lununburg Water District	Lunenburg	2162003	0.0	NO
J & M Golf, Inc.	Lunenburg		0.004	NO
Total			**0.46**	

Figure 2-15
Monthly Water Use Pattern, 1994-1998
Lunenburg



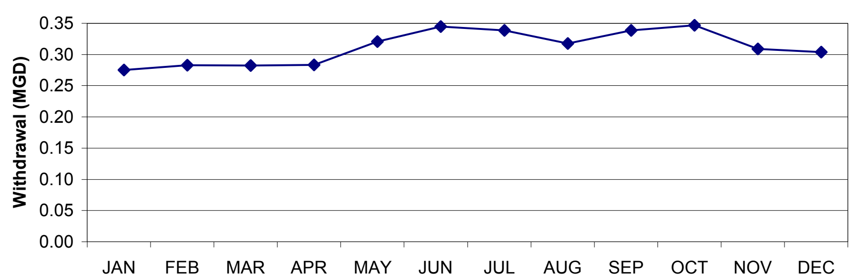
PWS Name	Town	PWS ID	Average Withdrawal (mgd)	Pattern Data
Aonebumskit Res	Paxton	2228000-01S	0.16	YES
Cournoyer Vegetable Farm	Paxton		0.0	NO
Total			**0.16**	

Figure 2-16
Monthly Water Use Pattern, 1994-1998
Paxton



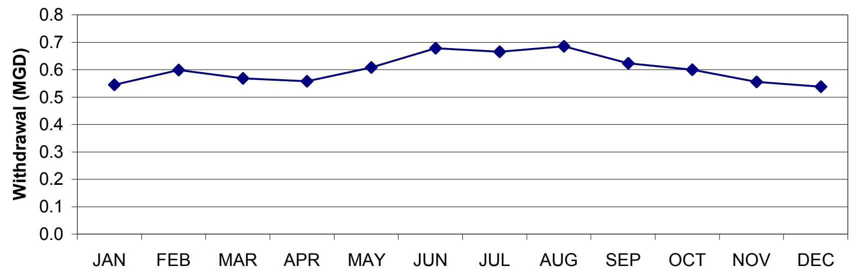
PWS Name	Town	PWS ID	Average Withdrawal (mgd)	Pattern Data
Pepperell Water	Pepperell	2232000-03G	0.06	YES
Pepperell Water	Pepperell	2232000-01G	0.68	YES
Pepperell Water	Pepperell	2232000-02G	0.35	YES
Pepperell Paper Co.	Pepperell		1.07	YES
Total			**2.16**	

Figure 2-17
Monthly Water Use Pattern, 1994-1998
Pepperell



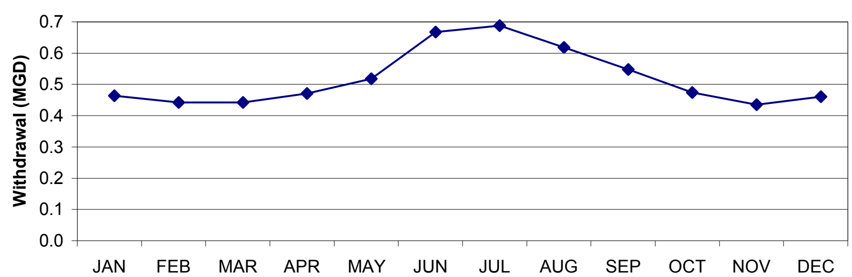
PWS Name	Town	PWS ID	Average Withdrawal (mgd)	Pattern Data
Muschopauge Pond	Rutland	2257000-01S	0.29	YES
C.S.B.C.W.S.	Rutland	2247003	0.001	YES
Total			**0.29**	

Figure 2-18
Monthly Water Use Pattern, 1994-1998
Rutland



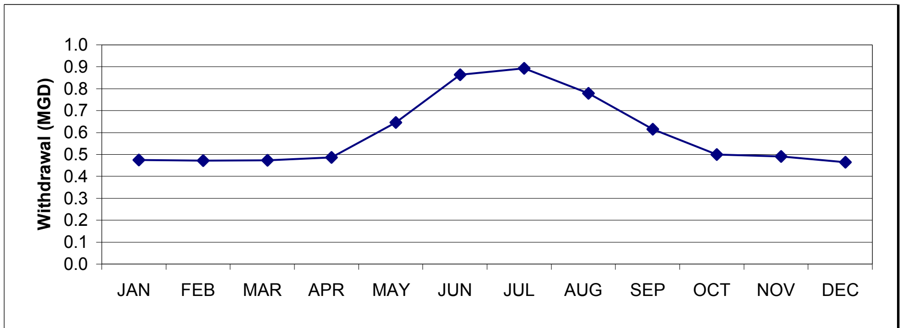
PWS Name	Town	PWS ID	Average Withdrawal (mgd)	Pattern Data
Shirley water District	Shirley	2270000-02G	0.06	YES
Shirley water District	Shirley	2270000-03G	0.23	YES
Shirley water District	Shirley	2270000-01G	0.0	NO
MCI Shirley	Shirley	2270011-01G	0.13	YES
MCI Shirley	Shirley	2270011-02G	0.17	YES
Woodland Ridge	Shirley	2270009-01G	0.001	YES
Woodland Ridge	Shirley	2270009-02G	0.004	YES
Total			**0.59**	

Figure 2-19
Monthly Water Use Pattern, 1994-1998
Shirley



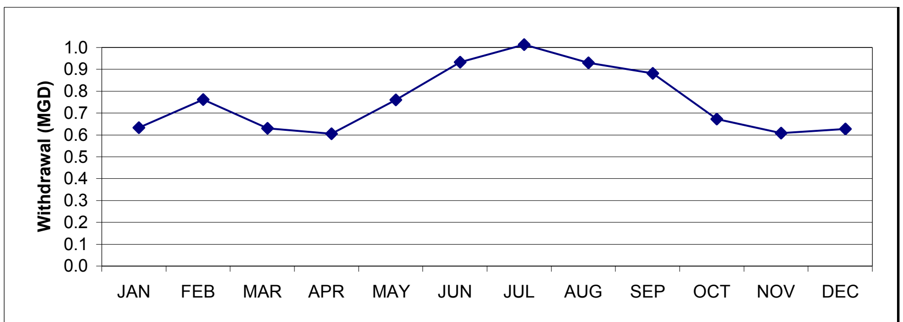
PWS Name	Town	PWS ID	Average Withdrawal (mgd)	Pattern Data
Sterling Water Dept.	Sterling	2282000-01G	0.0	NO
Sterling Water Dept.	Sterling	2282000-02G	0.04	YES
Sterling Water Dept.	Sterling	2282000-03G	0.11	YES
Sterling Water Dept.	Sterling	2282000-04G	0.18	YES
Sterling Water Dept.	Sterling	2282000-05G	0.14	YES
Thomson Gardens	Sterling		0.00	YES
Total			**0.47**	

Figure 2-20
Monthly Water Use Pattern, 1994-1998
Sterling



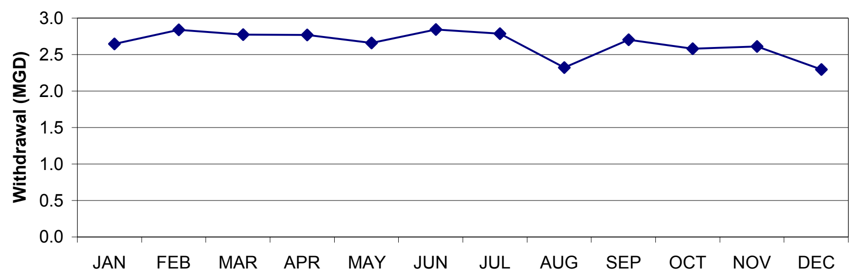
PWS Name	Town	PWS ID	Average Withdrawal (mgd)	Pattern Data
Townsend Water Dept	Townsend	2299000-01G	0.24	YES
Townsend Water Dept	Townsend	2299000-02G	0.18	YES
Witches Brook	Townsend	2299001-01G	0.16	YES
Willard Brook State Forest	Townsend	2299002	0.0005	NO
Pearl Hill State Park	Townsend	2299003-01G	0.0003	NO
Pearl Hill State Park	Townsend	2299003-02G	0.0013	NO
Total			**0.59**	

Figure 2-21
Monthly Water Use Pattern, 1994-1998
Townsend



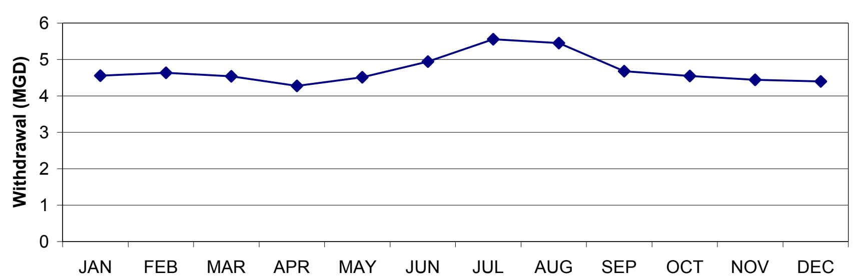
PWS Name	Town	PWS ID	Average Withdrawal (mgd)	Pattern Data
West Boylston Water District	West Boylston	2321000-04G	0.27	YES
West Boylston Water District	West Boylston	2321000-01G	0.23	YES
West Boylston Water District	West Boylston	2321000-05G	0.15	YES
Wachusett Country Club	West Boylston		0.04	YES
Total			**0.69**	

Figure 2-22
Monthly Water Use Pattern, 1994-1998
West Boylston



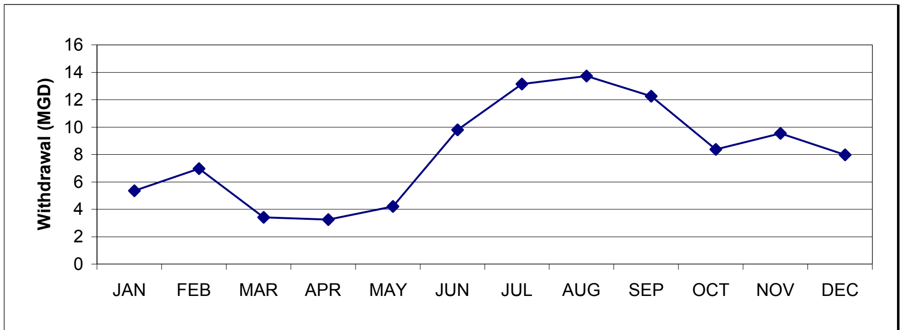
PWS Name	Town	PWS ID	Average Withdrawal (mgd)	Pattern Data
West Groton Water Supply	West Groton	2115001-01G	0.26	YES
Hollingsworth & Vose Co.	West Groton		2.36	YES
Total			**2.62**	

Figure 2-23
Monthly Water Use Pattern, 1994-1998
West Groton



PWS Name	Town	PWS ID	Average Withdrawal (mgd)	Pattern Data
Westminster Water Dept.	Westminster	2332000	0.0	NO
Westminster Golf Course	Westminster		0.05	YES
Total			**0.05**	

Figure 2-24
Monthly Water Use Pattern, 1994-1998
Westminster



PWS Name	Town	PWS ID	Average Withdrawal (mgd)	Pattern Data
Worcester DPW	Worcester	2348000	8.01	YES
Total			**8.01**	

Figure 2-25
Monthly Water Use Pattern, 1994-1998
Worcester

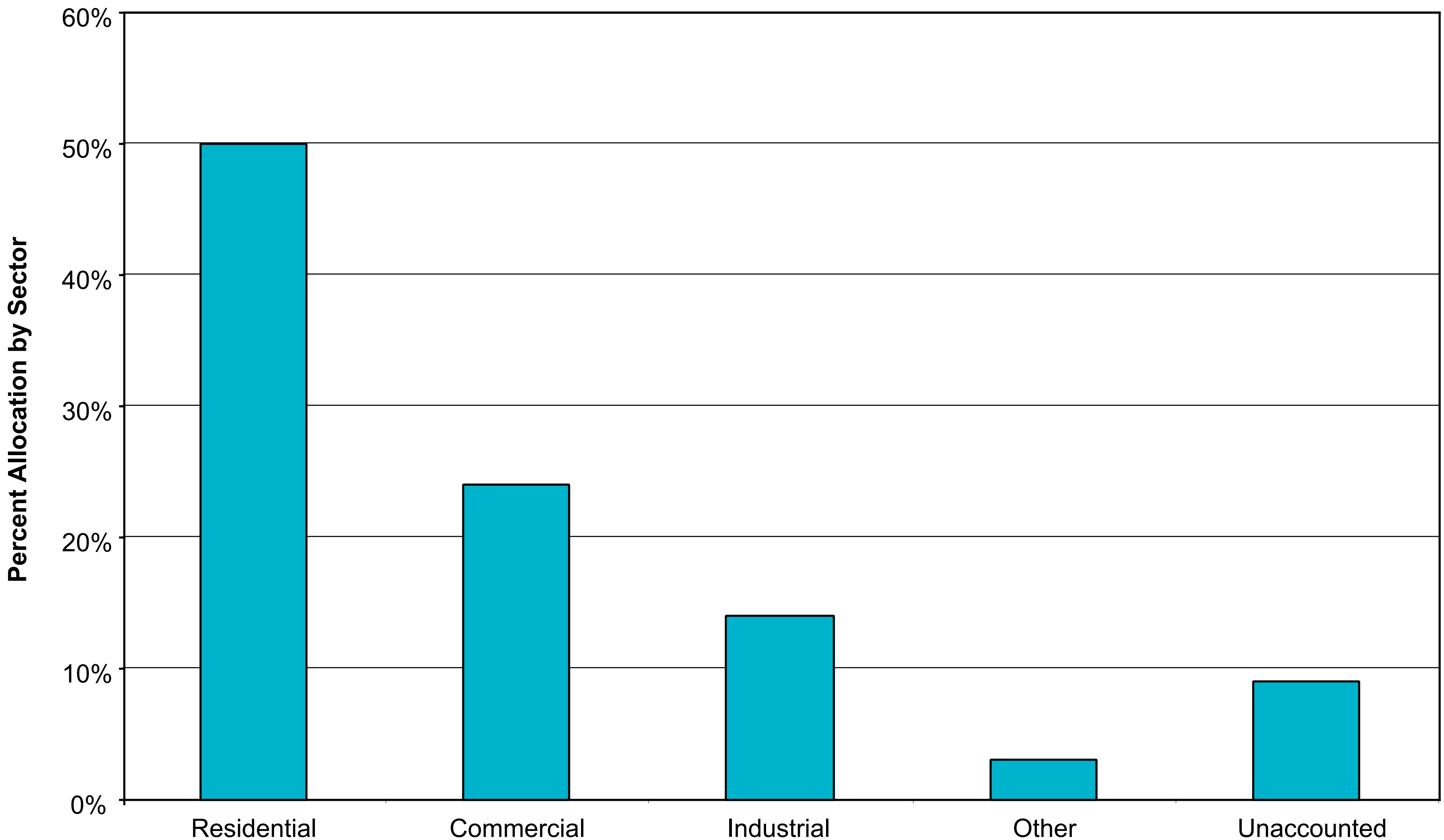


Figure 2-26
Monthly Water Use Allocation by Sector
Leominster

CDM

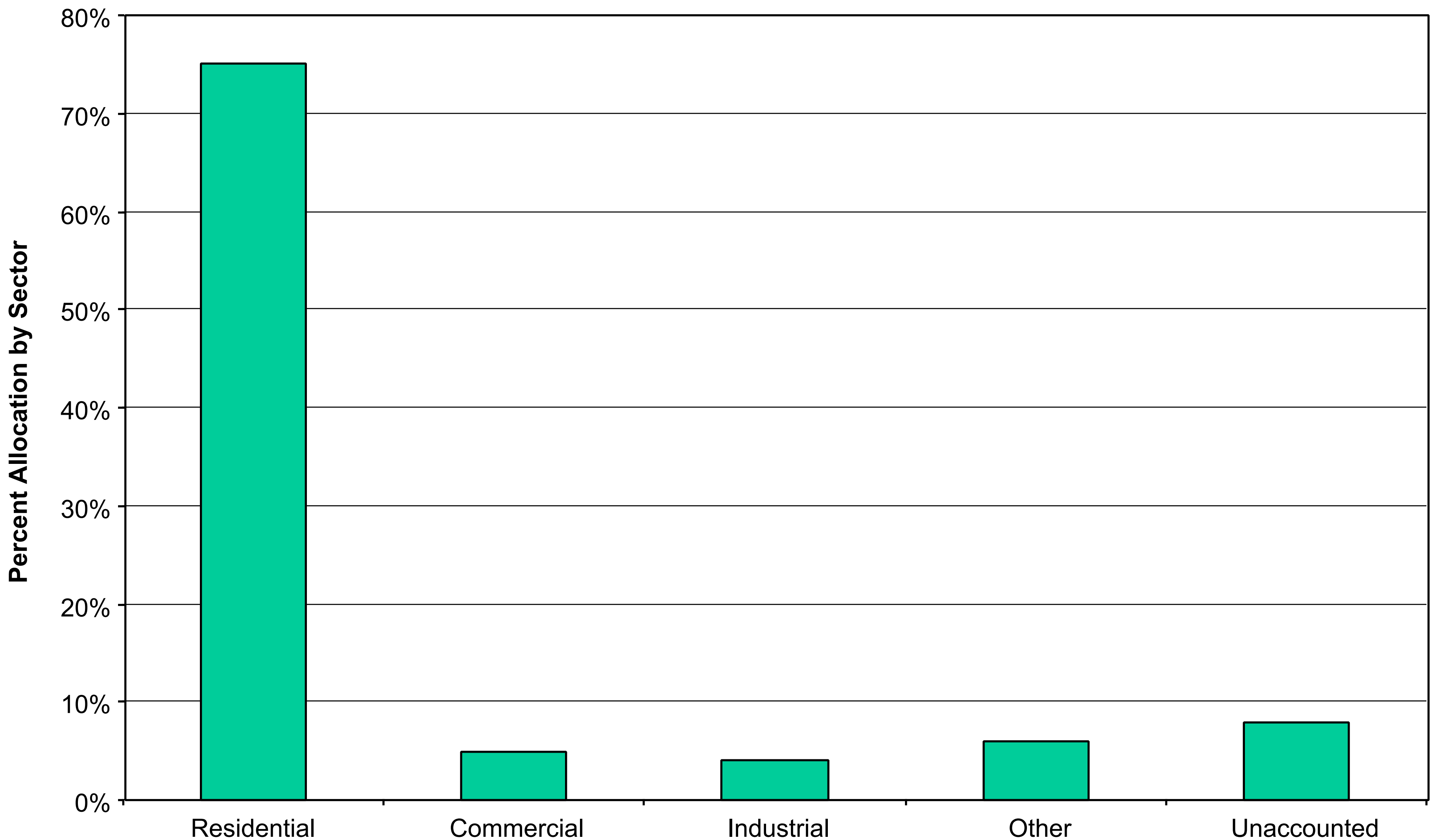


Figure 2-27
Monthly Water Use Allocation by Sector
Pepperell

CDM

11 mgd is private water supplies, and the remaining 6 mgd is small non-community water supplies that withdraw more than 100,000 gpd. Tables 2-3 and 2-6 present registered volumes for Public and Private Water Suppliers respectively.

- ***Water Withdrawal Permit.*** Permits are required for all water supply sources that withdraw more than 100,000 gpd or exceed their registration by more than 100,000 gpd. The permitted volume is approved by DEP and is in addition to any registered volume. The current water withdrawal permits for the Nashua Basin are valid from April 1999 through February 2004. Tables 2-3 and 2-6 present permitted volumes through the year 2014 for Public and Private Water Suppliers respectively.

- ***New Hampshire Registered Users.*** The New Hampshire Department of Environmental Services (NH DES) requires registration of all public and private water suppliers that withdraw over 20,000 gpd. There are four registered facilities in the study area: Nashua National Fish Hatchery, Sanmina Corporation, and Brox Industries in Nashua; and Overlook Golf Club in Mason. Note that of the New Hampshire communities within the Nashua River Basin only those containing tributaries that flow into Massachusetts will be included in this analysis. Therefore, although the City of Nashua is partly in the Nashua River Basin it will not be included in this analysis.

- ***Worcester and MWRA Operations.*** Worcester and the MWRA both withdraw substantial amounts of water from the Wachusett Watershed. Worcester maintains a system of supply reservoirs along the Quinapoxet River, upstream of Wachusett Reservoir. This system of reservoirs prevents nearly all normal stream flows from continuing downstream. The Wachusett Reservoir, which provides primary supply for the MWRA (in addition to Quabbin Reservoir, west of the study area), retains all flow from the Watershed upstream, except for a regular discharge of 1.8 mgd from the Wachusett Dam. MWRA pumps water from the Quabbin Reservoir into Wachusett Reservoir for temporary storage prior to transmission to the metropolitan Boston area. All flows greater than 1.8 mgd are stored in the reservoir for future use by MWRA customers in the Metropolitan Boston area.

Additional water use data needed to complete the inflow / outflow analysis include the following:

- Estimates of the existing and future areas served by public water supplies. This information is developed in Section 3 of this report.

2.5 Wastewater Discharges

Tables 2-7 and 2-8 present summary information on wastewater and process water discharges, and communities with Title 5 systems in the Nashua River Basin. Data presented in these tables were obtained from the following sources:

Table 2-7
Summary of Wastewater Discharge Information for Communities in the Nashua River Basin

MUNICIPALITIES	WASTEWATER DISPOSAL STATUS[1]	NPDES[2] DISCHARGE INFORMATION		TITLE 5 DISCHARGE INFORMATION
		NPDES FACILITIES	RECEIVING WATER BODY	RECEIVING BASIN
ASHBURNHAM	TITLE 5/ SEWER	to GARDNER WWTP	MILLERS	NASHUA/ MERRIMACK/ MILLERS
ASHBY	TITLE 5	N/A	-	NASHUA/ MERRIMACK
AYER	TITLE 5/ SEWERED	AYER WWTP	NASHUA	NASHUA
BOLTON	TITLE 5	N/A	-	NASHUA/ CONCORD
BOYLSTON	TITLE 5	N/A	-	NASHUA/ BLACKSTONE
CLINTON	TITLE 5/ SEWERED	CLINTON WWTP	NASHUA	NASHUA
DEVENS	TITLE 5/ SEWERED	DEVENS WWTP	NASHUA	NASHUA
DUNSTABLE	TITLE 5	N/A	-	NASHUA/ MERRIMACK
FITCHBURG	TITLE 5/ SEWERED	EAST FITCHBURG WWTP WEST FITCHBURG WWTP	NASHUA RIVER NORTH BRANCH NASHUA RIVER NORTH BRANCH	NASHUA
GARDNER	TITLE 5/ SEWERED	GARDNER WWTP	MILLERS	NASHUA/ MILLERS
GROTON/WEST G.	TITLE 5/ SEWERED	to PEPPERELL WWTP	NASHUA	NASHUA/ MERRIMACK
HARVARD	TITLE 5	N/A	-	NASHUA
HOLDEN	TITLE 5/ SEWER IN PROGRESS	to UPPER BLACKSTONE WWTP	BLACKSTONE	NASHUA/ BLACKSTONE
LANCASTER	TITLE 5/ SEWERED	to CLINTON WWTP	NASHUA	NASHUA
LEOMINSTER	TITLE 5/ SEWERED	LEOMINSTER WWTP	NASHUA	NASHUA
LUNENBURG	TITLE 5/ MJR SEWER PROPOSED	to LEOMINSTER or FITCHBURG	NASHUA	NASHUA
PAXTON	TITLE 5	N/A	-	NASHUA/ CHICOPEE/ BLACKSTONE
PEPPERELL	TITLE 5/ SEWER IN PROGRESS	PEPPERELL WWTP	NASHUA RIVER	NASHUA
PRINCETON	TITLE 5	N/A	-	NASHUA/ CHICOPEE
RUTLAND	TITLE 5/ SEWERED	to UPPER BLACKSTONE WWTP	BLACKSTONE	CHICOPEE/NASHUA
SHIRLEY	TITLE 5/ MJR SEWER PROPOSED	to DEVENS	NASHUA	NASHUA
STERLING	TITLE 5	N/A	-	NASHUA
TOWNSEND	TITLE 5	N/A	-	NASHUA
WEST BOYLSTON	TITLE 5/ SEWER IN PROGRESS	to UPPER BLACKSTONE WWTP	BLACKSTONE	NASHUA/ BLACKSTONE
WEST GROTON	TITLE 5	N/A	-	NASHUA
WESTMINSTER	TITLE 5/ SEWER IN PROGRESS	to FITCHBURG WEST	NASHUA	NASHUA/ CHICOPEE/ MILLERS
WORCESTER	SEWERED	to UPPER BLACKSTONE WWTP	BLACKSTONE	-

Notes:
[1] Information on wastewater disposal system status provided by Ning Chen (DEP CERO)
[2] National Pollutant Discharge Elimination System (NPDES) permit information obtained from DEP CERO files, reviewed by Bryant Firmin (DEP CERO)

Table 2-8
Summary of Process Water and Wastewater Discharge Information for Private Facilities in the Nashua River Basin

Permit Compliance System Facilities	Municipality	Permit Limit (MGD)	1996-98 Avg (MGD)	Type of Discharge	Receiving Water Body
Hollingsworth and Vose Co.	GROTON	no limit reported	2.43	Final Wastewater Effluent	Squannacook River
James River Corporation, Pepperell Inc.	PEPPERELL	1.50	1.38	Final Wastewater Effluent	Nashua River
Simonds Industries, Inc.	FITCHBURG	0.49	0.27	Cooling water: non-contact & air conditioning	Nashua River
MCI-Shirley	SHIRLEY	0.27	0.18	Final Wastewater Effluent	Nashua River
Indeck Pepperell Power Association	PEPPERELL	0.13	0.06	Cooling water and stormwater	Nashua River/James River WWTP
The Kelly Co.	CLINTON	0.05	0.03	Non- contact cooling water & stormwater	Counterpane Brook- Nashua River
Groton School	GROTON	0.03	0.03	Final Wastewater Effluent	Nashua River
PJ Keating	LUNENBURG	N/A	0.01	Stormwater	Bow Brook and Lake Shirley
River Terrace	LANCASTER	0.01	0.00	Final Wastewater Effluent	North Nashua via storm drain
Total Discharge, Permitted and 2-year Average (MGD):		2.47	4.39		

Notes:
Reviewed by Bryant Firmin (DEP CERO) 8/99 and 2/00

- ***EPA National Pollutant Discharge Elimination System (NPDES) Discharge Monitoring Reports from 1996 through 1998***. NPDES permits include major and minor reporting categories and are required for any discharge of pollutants to surface waters. Discharge Monitoring Reports include maximum, minimum and average daily flows and permit limits.

  Table 2-7 presents a summary of wastewater discharge information for communities in the Nashua River Basin. Tables 2-8 and 2-9 present information on permit limits, average annual discharges, and receiving water bodies for private and public NPDES-permitted facilities respectively. Table 2-8 shows the nine major NPDES-permitted Private Facilities within the Nashua River Basin. Their total annual permit discharge limit is 2.5 mgd. Hollingsworth and Vose, Co. is not included the total permitted discharge because no limit was reported. The 1996-98 average discharge by private facilities was 4.4 mgd. Table 2-9 lists the seven municipal-owned Wastewater Treatment Plants (WWTPs) in the Nashua Basin and their total permitted annual discharge- approximately 41 mgd. The 1996-98 average discharge was 22.59 mgd.

- **DEP Central Regional Office (CERO).** Through telephone conversations and review of tables, Ning Chen (DEP CERO) provided information regarding ongoing and proposed sewer projects. This information in summarized in Table 2-7.

Additional discharge data needed to complete the inflow / outflow analysis (Section 6) include the following:

- Monthly wastewater discharges from 1996 through 1998 for wastewater treatment plants that are outside of the Nashua River Basin but serve communities within the basin (i.e., Upper Blackstone WWTP and Gardner WWTP).

- Collection estimates for proposed sewer systems (i.e., Lunenburg and Shirley).

- Estimates of the existing and future areas served by sewer.

This information is developed in Section 5 of this report.

2.6 Population

Table 2-10 includes measured, estimated and predicted population data for communities in the Nashua River Basin from the following sources:

- ***US Census***. Census data include 1980, 1990 and estimated population for 1995.

- ***Massachusetts Institute of Social and Economic Research (MISER).*** MISER data include predicted population for 2000, 2005 and 2010.

To conduct water demand projections, the MA Department of Environmental Management (DEM) usually uses population growth estimates from the regional

Table 2-9
Summary of Discharge Information for Public Wastewater Treatment Plants in the Nashua River Basin

Permit Compliance System Facilities	Municipality	Permit Limit (MGD)	1996-98 Avg (MGD)	Receiving Water Body
E. Fitchburg WWTP	FITCHBURG	12.40	6.88	Nashua River North Branch
Leominster WWTP	LEOMINSTER	9.30	5.93	Nashua River North Branch
W. Fitchburg WWTP	FITCHBURG	10.50	4.82	Nashua River North Branch
Clinton WWTP	CLINTON	3.01	2.67	Nashua River South Branch
Ayer WWTP	AYER	1.79	1.37	Nashua River
Pepperel WWTP	PEPPERELL	0.71	0.48	Nashua River
Devens WWTP	DEVENS	3.00	0.44	Nashua River
Total Discharge, Permitted and 2-year Average (MGD):		40.71	22.59	

Notes:
Reviewed by Bryant Firmin (DEP CERO) 8/99

Table 2-10
Summary of Miser Mid-Level Population Projections to 2010: Massachusetts Cities and Towns

Community	Census 1980	Census 1990	Estimated 1995	MISER Predicted 2000	2005	2010	% Change (20 years)
Middlesex County							
Ashby	2,311	2,717	2,583	2,630	2,648	2,664	-1.95%
Ayer	6,993	6,871	5,565	5,256	4,998	4,766	-30.64%
Dunstable	1,671	2,236	2,663	3,221	3,788	4,375	95.66%
Groton	6,154	7,511	8,770	9,962	11,076	12,164	61.95%
Pepperell	8,061	10,098	10,742	11,482	12,230	13,010	28.84%
Shirley	5,124	6,118	6,251	6,756	7,121	7,448	21.74%
Townsend	7,201	8,496	9,076	9,500	10,064	10,762	26.67%
Worcester County							
Ashburnham	4,075	5,433	5,998	6,841	7,795	8,822	62.38%
Bolton	2,530	3,134	3,830	4,351	4,832	5,318	69.69%
Boylston	3,470	3,517	3,806	3,927	3,973	4,006	13.90%
Clinton	12,771	13,222	13,531	13,556	13,527	13,609	2.93%
Fitchburg	39,580	41,194	38,828	38,278	37,980	37,947	-7.88%
Gardner	17,900	20,125	20,481	21,261	22,133	23,272	15.64%
Harvard	12,170	12,329	11,477	13,105	14,818	16,707	35.51%
Holden	13,336	14,628	15,612	16,435	17,137	17,758	21.40%
Lancaster	6,334	6,661	6,935	7,220	7,442	7,619	14.38%
Leominster	34,508	38,145	40,368	42,253	43,826	45,635	19.64%
Lunenburg	8,405	9,117	9,758	10,336	10,757	11,090	21.64%
Paxton	3,762	4,047	4,213	4,503	4,783	5,026	24.19%
Princeton	2,425	3,189	3,351	3,616	3,850	4,103	28.66%
Rutland	4,334	4,936	5,629	6,148	6,651	7,167	45.20%
Sterling	5,440	6,481	6,977	7,527	8,019	8,438	30.20%
West Boylston	6,204	6,611	6,807	7,084	7,299	7,477	13.10%
Westminster	5,139	6,191	6,218	6,629	7,058	7,539	21.77%
Worcester	161,799	169,759	168,486	169,726	172,290	176,753	4.12%

planning agencies (RPAs) and compares these with other sources to determine the most accurate estimate for each community. Three RPAs--Montachusett, Central Mass, and Northern Middlesex Council of Governments—cover the Nashua Basin. The Montachusett RPA used MISER data for their Nashua River Watershed Growth Plan (1998).

2.7 Streamflow

Table 2-11 presents summary information on continuous and partial record USGS streamflow data for the Nashua River Basin. There are six continuous record gauges, two peak-flow gauges, and seven low-flow, partial record sites in the basin. Figure 2-28 presents the locations of the continuous USGS gauging stations in the Nashua River Watershed. For each of the continuous record USGS stream flow gauges, Table 2-12 summarizes the average monthly and 7Q10 flows. The average monthly flows at each of the gauging stations are presented in Figures 2-29 through 2-34.

Table 2-11
Summary of USGS streamflow data for the Nashua River Basin

USGS Station Name	USGS Gauge ID	Drainage Area (mi^2)	Streamflow Data Type	Period of Record
North Nashua River At Fitchburg, MA	1094400	63.4	continuous	1972 to present
North Nashua River Near Leominster, MA	1094500	110	continuous	1935 to present
Quinapoxet River At Canada Mills Near Holden, MA	1095375	44.4	continuous	1996 to present
Squannacook River Near West Groton, MA	1096000	63.7	continuous	1949 to present
Nashua River At East Pepperell, MA	1096500	316	continuous	1935 to present
Stillwater River near Sterling, MA	1095220	31.6	continuous low flow partial record	1994 to present 1971-73, 1991-93
Rocky Brook Near Sterling, MA	1095000	1.95	peak	1946 to 1967
Easter Brook Near North Leominster, MA	1095800	0.92	peak	1964 to 1974
Trapfall Brook Near Ashby, MA	1095928	5.89	low flow partial record	1993 to 1995
Trout Brook Near Holden, MA	1095380	6.79	low flow partial record	1971-73, 1991-93
Philips Brook At Fitchburg, MA	1094396	15.8	low flow partial record	1994 to 1996
Whitman River Near Westminster, MA	1094340	21.7	low flow partial record	1973-74, 1991-93
Unkety Brook Near Pepperell, MA	1096505	6.84	low flow partial record	1971-74, 1991-93
Reedy Brook Near E. Pepperell, MA	1096504	1.92	low flow partial record	1971-73, 1991-93

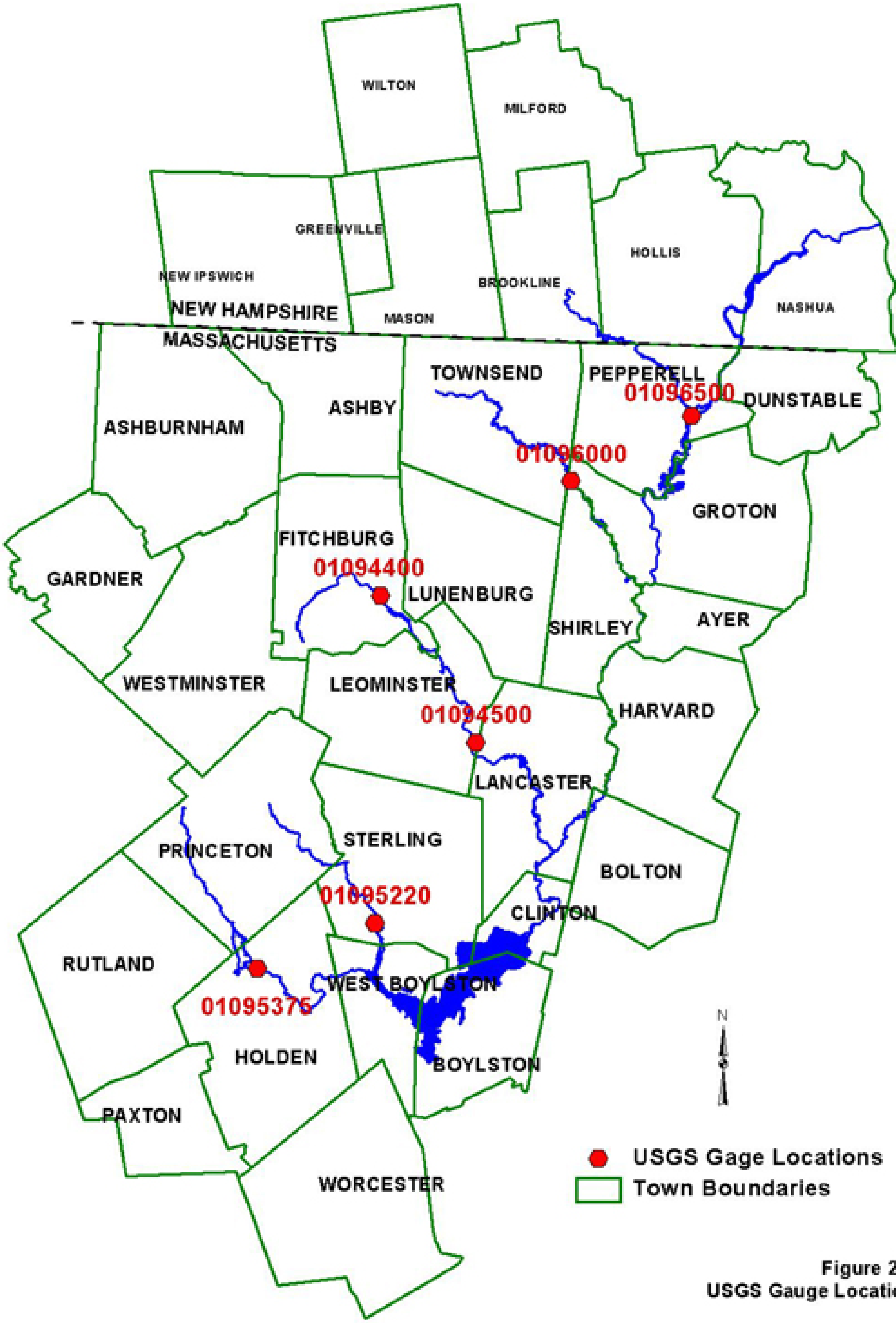


Figure 2-28
USGS Gauge Locations

Table 2-12
Average Monthly Flow at Continuous Gauges

Month	USGS Stream Gage ID					
	1096500 Flow (cfs)	**1096000 Flow (cfs)**	**1095375 Flow (cfs)**	**1095220 Flow (cfs)**	**1094500 Flow (cfs)**	**1094400 Flow (cfs)**
January	621	124	91	103	215	142
February	684	135	98	86	231	143
March	1143	229	174	113	383	234
April	1251	268	136	96	412	240
May	727	148	92	63	245	144
June	486	83	67	32	164	93
July	252	37	19	17	90	46
August	213	29	5	9	81	46
September	233	32	8	11	88	43
October	318	55	10	32	117	80
November	484	100	24	50	175	118
December	602	123	90	72	207	141
7Q10	28.7	4.2	0.65	0.64	21.2	5.7

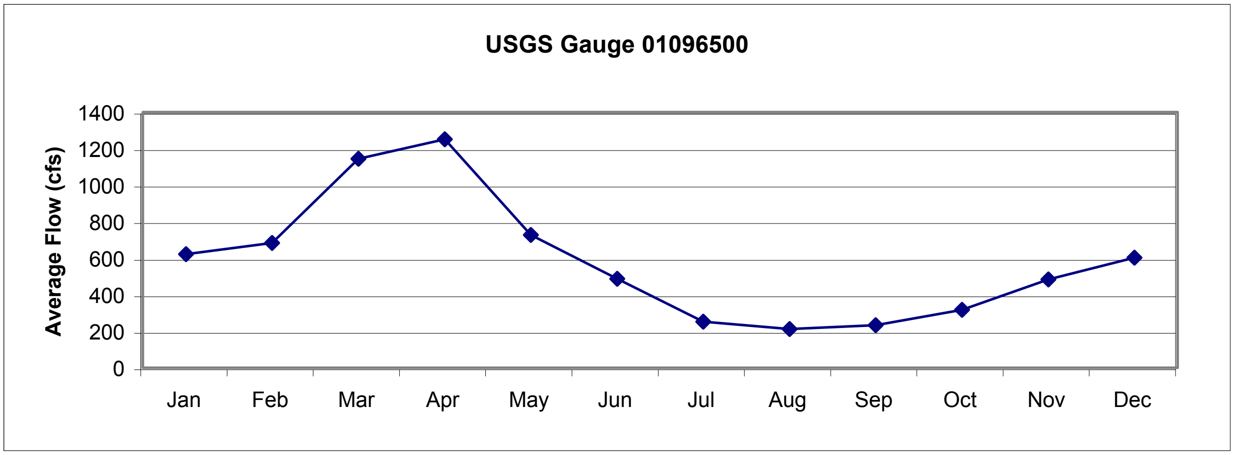


Figure 2-29
Average Monthly Flow
Nashua River at E. Pepperell

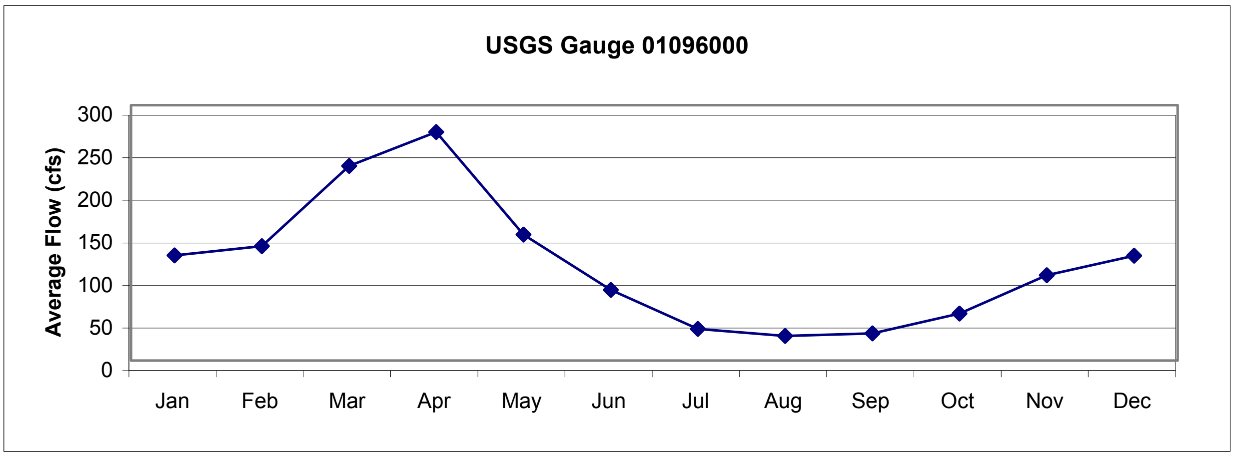


Figure 2-30
Average Monthly Flow
Squannacook River near W. Groton

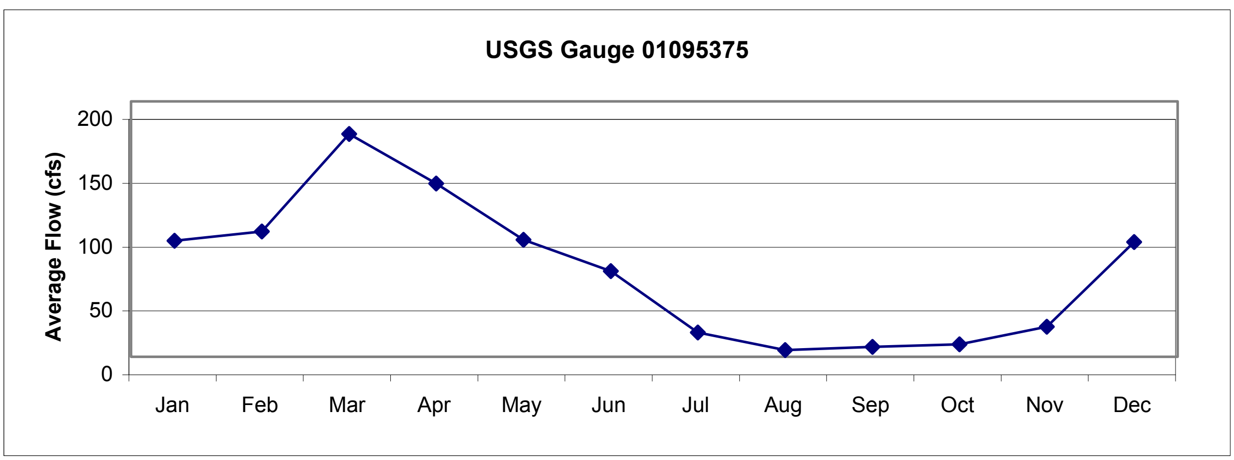


Figure 2-31
Average Monthly Flow
Quinapoxet River

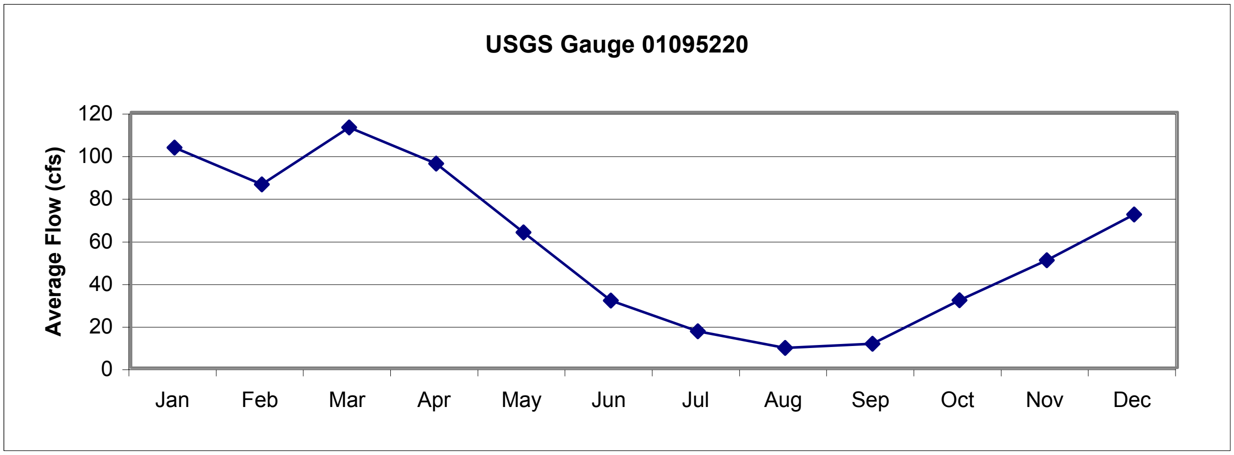


Figure 2-32
Average Monthly Flow
Stillwater River

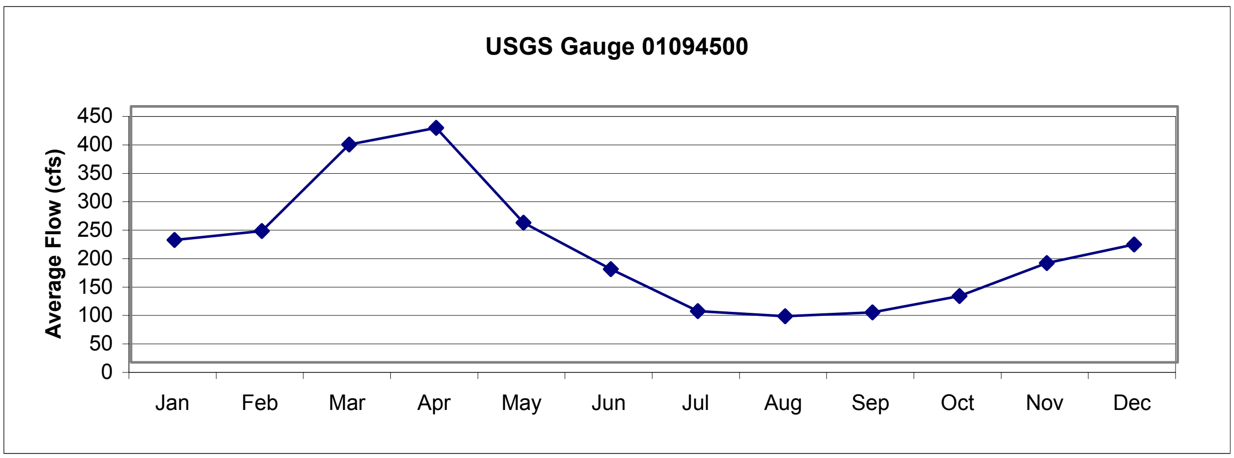


Figure 2-33
Average Monthly Flow
N. Nashua River near Leominster

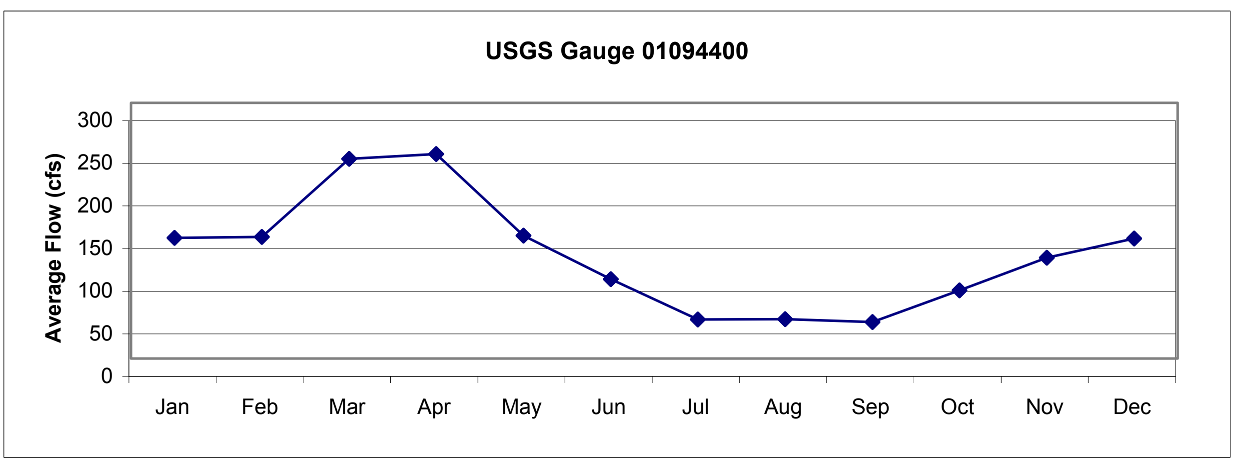


Figure 2-34
Average Monthly Flow
N. Nashua River at Fitchburg

Section 3
Water Supply Needs

3.1 General

This section presents estimates of the current average (2000) water needs and future (through 2020) water needs for the Nashua River Watershed communities that obtain their water from sources within the watershed. These communities are identified in Section 3.2. The water service areas for each of these communities are described in Section 3.3. The approach used in projecting future water needs follows the "Policy for Developing Water Needs Forecasts for Public Water Supplies," dated February 8, 2001 (Appendix B), that has been approved by the Massachusetts Water Resources Commission and used by the Department of Management, Office of Water Resources (OWR) in assisting communities develop Water Needs Forms for Water Management Act permits and is described in Section 3.4. Section 3.5 discusses in detail the methodologies used to estimate future water demands, and the resulting calculations are presented in Section 3.5.2. Section 3.6 provides a water conservation assessment of communities in the Nashua River Watershed.

3.2 Watershed Communities

Current and future water needs projections were developed for all communities that have a significant area and population within the Nashua River Watershed and that have a source of public water supply within the watershed. These communities are identified in Figure 3-1. Ashburnham, Dunstable, and Gardner have a small but significant portion of their areas within the basin, but are not included because they obtain all of their public water supply from sources outside the basin; Bolton is partially within the watershed, but it has no public water supply. Similarly, Ashby and Princeton are not included because they do not have a public water supply although they are located mostly within the basin.

3.3 Water Service Areas

Existing and future water service areas were required for the analysis to distribute known flows between the subbasins within each municipality in an appropriate manner. Service areas were determined using one of three possible methods:

- **Available GIS Coverage:** If GIS coverage of the water distribution piping was available for a community, then the coverage of the piping was used to determine the service area. The percentage of the water distribution system (calculated by length of pipe) in each subbasin was used to distribute flows among the subbasins.

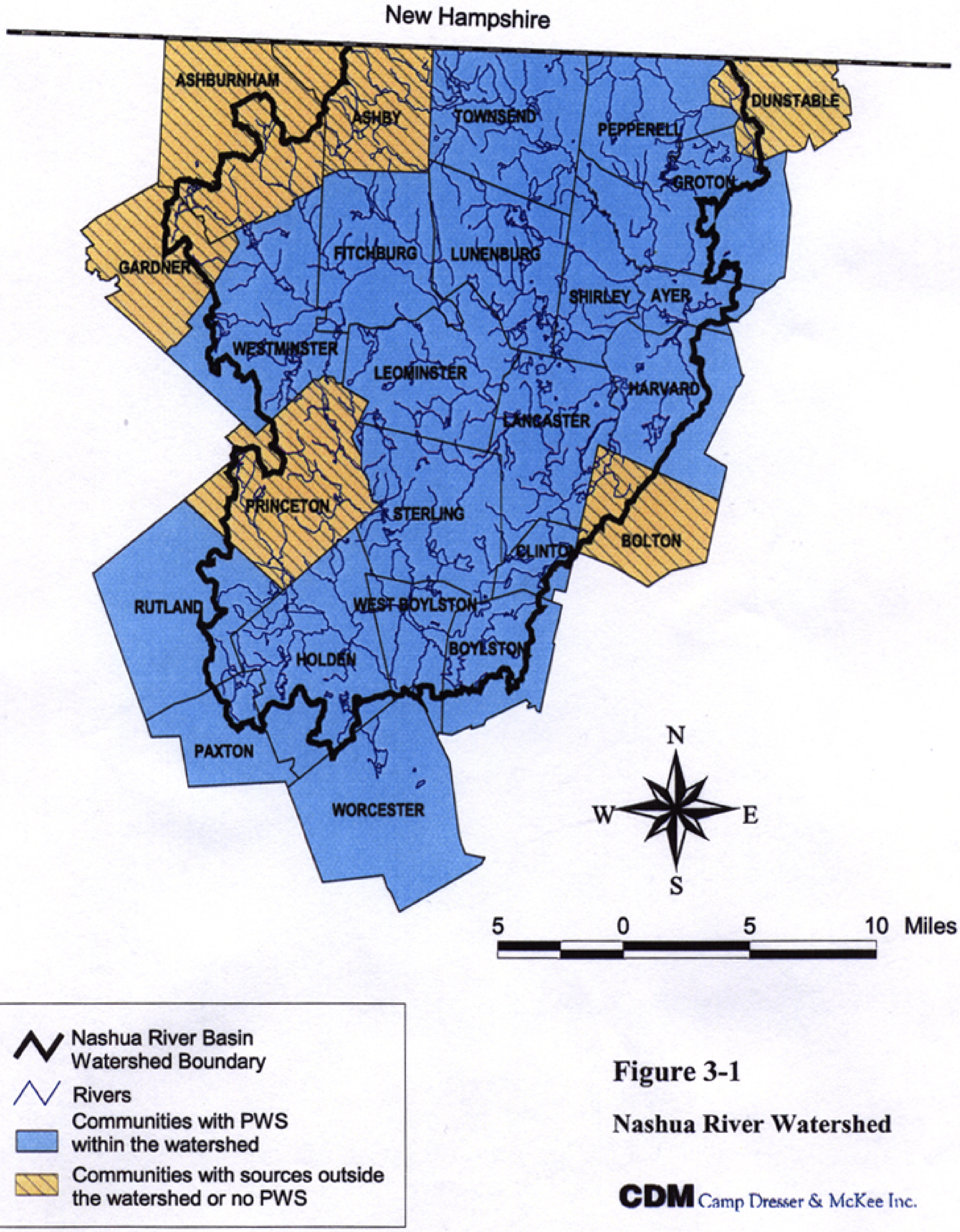


Figure 3-1

Nashua River Watershed

- **Utility Contact:** If GIS coverage of the water distribution system was not available, a representative of the utility for the municipality was contacted. If possible, the data was provided either through hard-copy maps or through conversations with the representative and was used to establish the service area. Maps provided by municipalities or developed through conversations with municipal authorities were used in conjunction with MassGIS land use data to determine service areas. The percentage of each service area falling in a particular subbasin was used to distribute flows within the community.

- **MassGIS Land Use Data:** If data were not available through either of the first two means, then MassGIS land use data were used to approximate service areas. Using MassGIS data, water service was assumed to be provided to all developed land uses: Industrial, Commercial, Residential-Multi Family, Residential-Small Lots, Residential-Medium Lots, and Residential-Large Lots. The approximate areas served by public water supplies were verified using 1990 census block data. Census block data contains information on homes served by public water. After approximating the service areas using MassGIS data, the method of distributing flow among the subbasins was the same as when maps were provided by the municipalities.

Exhibit A presents the water service areas obtained using the three methods described above. Table 3-1 summarizes the existing water service information, including the method of determining the distribution of water within each community as well as the subbasins to which each system distributes water. Because the water systems of non-public registered and permitted water users are typically small compared with both municipal distribution areas and with the scale of interest of this study, all non-public supplies were distributed to the same subbasin from which they were withdrawn. These supplies are identified as points in Exhibit A.

In all municipalities, substantial growth of the water distribution system was either not expected to occur or specific plans for the expansion of the water system were not yet available. Therefore, existing service areas were used to distribute future flows.

3.4 Forecasted Population Growth

3.4.1 Methodology

The WRC approved Water Needs Forms (WNF) methodology used by DEM consists of two approaches, referred to as Method 1 and Method 2, depending on the data that pertains to a particular community. The WNF policy is attached in Appendix B.

Method 1 is used to project future water demands for those communities that can provide adequate dis-aggregated water use data, have a residential average daily demand (ADD) of 80 gallons per capita per day (gpcd) or less and have an unaccounted-for water use equal to 15 percent or less of its total average daily

Table 3-1

Summary of Existing Water Service Information

Community	Presence of Public Water Supply	Source of Service Area Information	Public Water Supply Source Basin
Ashby	*All Private*	N/A	Nashua
Bolton	*All Private*	N/A	Nashua/ Concord
Princeton	*All Private*	N/A	Nashua/ Chicopee
Ashburnham	PWS	GIS Coverage	Millers
Ayer	PWS	GIS Coverage	Nashua
Boylston	PWS	GIS Coverage	Nashua/ Blackstone
Clinton	PWS	MassGIS Land Use	Nashua/ Quabbin
Devens	PWS	GIS Coverage	Nashua
Dunstable	PWS	MassGIS Land Use	Merrimack
Fitchburg	PWS	MassGIS Land Use	Nashua
Gardner	PWS	GIS Coverage	Millers
Groton	PWS	MassGIS Land Use	Nashua/ Merrimack
Harvard	PWS	MassGIS Land Use	Nashua
Holden	PWS	GIS Coverage	Nashua/ Blackstone
Lancaster	PWS	Utility Contact	Nashua
Leominster	PWS	MassGIS Land Use	Nashua
Lunenburg	PWS	GIS Coverage	Nashua
Paxton	PWS	MassGIS Land Use	Nashua
Pepperell	PWS	Utility Contact	Nashua
Rutland	PWS	GIS Coverage	Nashua/ Chicopee
Shirley	PWS	GIS Coverage	Nashua
Sterling	PWS	GIS Coverage	Nashua
Townsend	PWS	MassGIS Land Use	Nashua
West Boylston	PWS	GIS Coverage	Nashua
Westminster	PWS	Utility Contact	Nashua/ Chicopee
Worcester	PWS	MassGIS Land Use	Nashua/ Blackstone

PWS: public water supply Present

demand. Method 2, a simplified and more conservative method for estimating future water demands, is used for communities which do not meet the requirements of Method 1. These two methods are illustrated in Figure 3-2, and are described in detail below.

As can be seen from Figure 3-2, both methods rely heavily on estimates of a future service population for estimating the future water needs of the community, as well as the existing ADD.

3.4.2 Current Populations and Future Projections

In its projections of future water needs, the Massachusetts DEM uses population growth estimates from the designated regional planning agencies (RPAs) covering the communities involved. The population projections used in this analysis came from several sources, including the Massachusetts Institute for Social and Economic Research (MISER), the Metropolitan Area Planning Council (MAPC), the Central Massachusetts Regional Planning Council (CMRPC), the Northern Middlesex Council of Governments (NMCOG), and ENSR, an environmental consulting firm. The projections for each Town were selected based on meetings and telephone conversations between CDM and DEM. Table 3-2 summarizes the population projections used in this analysis for each community, as well as the source of the data.

3.5 Water Needs Forcasts

3.5.1 Methodologies

Future water needs projections have been calculated for each community in the Nashua River Watershed using both DEM Method 1 and Method 2 to be able to compare the results and differences that would be obtained. Both methods use dis-aggregated data taken from each community's Annual Statistic Reports (ASRs) where it is available. The data taken from these reports are broken up into three categories; percent residential average daily demand (ADD), non-residential water ADD (sum of commercial, industrial, agricultural, and municipal ADD), and unaccounted for water (UAW), which is the difference between the pumped and metered water supplies.

Although these forecasts of community water needs were prepared using WRC-approved methodology, they should not be used in preparing WMA permit applications without consulting DEM.

The calculations performed and results obtained are shown in Table 3-3 for Method 1 and Table 3-4 for Method 2. The calculation process used to obtain these results according to the current DEM methods are described as follows.

Method 1 – Disaggregated Water Demand Projection

Method 1 can be used to project future water demands for those communities which can provide adequate disaggregated water use data, have a residential ADD of 80 gallons per capita per day (gpcd) or less, and have a percent UAW ADD of 15% or

Figure 3-2
WATER NEEDS FORECASTING METHODOLOGY

KNOWN OR GIVEN:

Base POP

Base ADD

2020 POP Projection -- from Regional Agency or MISER

Base Service POP %

% RES, % NON RES, % UAW (if known)

COMPUTE:

Base Service POP = Base POP x Base Service POP%

Base RES GPCD =(Base ADD x % RES)/ Base Service POP

Base Non-RES GPCD =(Base ADD x %Non-RES)/Base POP

2020 Service POP % -- Increase at 5%/decade if >90%
Increase at 10%/decade if <90%

2020 Service POP = 2020 POP x 2020 Service POP %

IF: 1) Disaggregated Water Use Data is Available,
2) RES GPCD is 80 or less, AND
3) %UAW is 15% or less
Then use METHOD #1, otherwise must use METHOD #2

METHOD #1

Uses Disaggregated Water Use Data to Compute 2020 Residential, Non-Residential, and UAW ADD

2020 RES ADD = 2020 Service POP x Base RES GPCD (< 80 gpcd)

2020 NON-RES ADD = Base Non-RES ADD + (POP Change x Base Non-RES GPCD) + Non-RES ADD growth

2020 UAW ADD -- Use Base % UAW if < 10%, or if > 10%, decrease to 10% by 2020.

2020 ADD =
RES ADD + Non-RES ADD + UAW ADD

METHOD #2

Uses Simplified Methodology to Estimate 2020 Increases in Residential and Non-Residential ADD. **Assumes that conservation will decrease use.**

2020 Incr. in RES ADD = (2020 Service POP - Base Service POP) x Base RES GPCD (<70 gpcd)

2020 Incr. in NON-RES ADD = (POP Change x Base Non-RES GPCD) + **Slower** Non-RES growth

Uses **no allowance for UAW** (included in Base ADD).

2020 ADD =
Base ADD + Incr. in RES ADD + Incr. in Non-RES ADD

Table 3-2

Summary of Population Data

Community	Estimated Population (2000)	Population (2020)	Data Source	Census Population (2000)
Ayer	6,741	9,956	ENSR	7,287
Boylston	3,927	4,375	CMRPC	4,008
Clinton	13,455	14,423	MAPC	13,435
Fitchburg	38,278	37,890	MISER Mid	39,102
Groton	9,509	13,241	MAPC	9,547
Harvard	5,364	6,550	ENSR	5,981
Holden	16,221	17,215	CMRPC	15,621
Lancaster	6,628	7,478	MAPC	7,380
Leominster	42,253	49,300	MISER Mid	41,303
Lunenburg	9,400	11,750	MISER Mid	9,400
Paxton	4,209	4,713	CMRPC	4,386
Pepperell	11,756	13,975	NMCOG	11,142
Rutland	6,148	8,200	MISER Mid	6,353
Shirley	5,966	7,550	ENSR	6,373
Sterling	7,250	9,290	MISER Mid	7,257
Townsend	9,500	12,200	MISER Mid	9,198
West Boylston	6,965	7,392	CMRPC	7,481
Westminster	7,001	8,500	MISER Mid	6,907
Worcester	170,163	178,123	CMRPC	172,648

Notes:

MISER Mid– Massachusetts Institute for Social and Economic Research
MAPC – Metropolitan Area Planning Council
CMRPC – Central Massachusetts Regional Planning Commission
NMCOG – Northern Middlesex Council of Governments
ENSR – ENSR (environmental consulting firm)

Table 3-3 Average Daily Demands as calculated by Method 1

Community	Public Water Supply	Population (2000)	Base Service Population %	Base Service Population	Base ADD (1)	Base ADD	% Residential ADD	Residential ADD	%Non Residential ADD	Non Residential ADD	% UAW ADD	UAW ADD	2020 Estimated Population	2020 Service Population %	2020 Service Population	Service Population Change	2020 Res ADD	Increase in Non Res ADD (Pop. Change)	Increase in Non Res ADD (ASR Trends)	2000 Non Res ADD	Total 2020 Non Res ADD	2020 % UAW ADD	2020 UAW ADD	2000 ADD	2020 ADD
A		B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	Ra	Rb*	S	T	U	V	W	X
					MGD	GPCD		GPCD		GPCD		GPCD					MGD			MGD	MGD		MGD	MGD	MGD
				BxC		E/D		FxG		FxI		FxK			MxN	O-D	HxO	JxP		ExI	R+S		ExU	E	Q+T+V
Ayer		6,741	99	6,650	1.08	162	40	65	50	81	10	16	9,956	100	9,956	3,306	0.65	0.27	0.00	0.54	0.81	10	0.11	1.08	1.56
Boylston	BWD	3,927	35	1,371	0.30	219	36	79	54	118	10	22	4,375	45	1,969	598	0.16	0.07	0.16	0.16	0.39	10	0.03	0.3	0.58
Groton	WGWSD	9,509	20	1,883	0.18	96	50	48	48	46	2	2	13,241	26	3,443	1,559	0.16	0.07	0.00	0.09	0.16	2	0.00	0.18	0.33
Harvard		5,364	3	160	0.02	125	54	68	37	46	10	13	6,550	23	1,507	1,347	0.10	0.06		0.01	0.07	10	0.00	0.02	0.17
Leominster		42,253	89	37,681	4.06	108	50	54	41	44	9	10	49,300	100	49,300	11,619	2.66	0.51	0.00	1.66	2.18	9	0.37	4.06	5.20
Lunenburg		9,400	69	6,452	0.44	68	74	50	13	9	13	9	11,750	89	10,458	4,006	0.53	0.04	0.00	0.06	0.09	10	0.04	0.44	0.66
Paxton		4,209	84	3,536	0.32	90	82	74	14	13	4	4	4,713	100	4,713	1,177	0.35	0.01	0.00	0.04	0.06	4	0.01	0.32	0.42
Rutland		6,148	62	3,824	0.35	92	81	74	8	7	11	10	8,200	82	6,724	2,900	0.50	0.02	0.06	0.03	0.11	10	0.04	0.35	0.64
Shirley	SDW	5,966	56	3,341	0.29	87	87	76	7	6	6	5	7,550	76	5,738	2,397	0.43	0.01	0.00	0.02	0.03	6	0.02	0.29	0.49

Notes:
1 - Data taken from most recent ASRs
NR - Data not reported
Holden does not have disaggregated data.

*Column Rb is dependent upon the 10 previous years' growth trends but is calculated on the data that we have now (5 years).

Table 3-4 Average Daily Demands as calculated by Method 2

Community	Public Water Supply	Population (2000)	Base Service Population %	Base Service Population	Base ADD (1)	Base ADD	% Residential	Residential ADD	%Non Residential ADD	Non Residential ADD	% UAW ADD	UAW ADD	2020 Estimated Population	2020 Service Population %	2020 Service Population	Service Population Change	Residential ADD Factor	Increase In Res ADD	Increase in Non Res ADD (Pop. Change)	Increase in Non Res ADD (ASR Trends)	2000 ADD	2020 ADD
A		B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	Sa	Sb*	T	U
					MGD	GPCD		GPCD		GPCD		GPCD					GPCD	MGD	MGD	MGD	MGD	MGD
				BxC		E/D		FxG		FxI		FxK			MxN	O-D	H	PxQ	FxIxP		E	R+S+T
Boylston	MWD	3,927	35	1,371	0.18	131	47	62	5	7	48	63	4,375	45	1,969	598	62	0.04	0.00	0.02	0.18	0.24
Clinton		13,455	100	13,455	2.04	152	68	103	32	49	1	2	14,423	100	14,423	968	70	0.07	0.05	0.05	2.04	2.20
Fitchburg		38,278	100	38,448	5.95	155	35	54	46	71	19	29	37,890	100	37,890	(558)	54	-0.03	-0.04	0.00	5.95	5.88
Groton	GWD	9,509	46	4,346	0.41	94	87	82	13	12	NR		13,241	60	7,945	3,599	70	0.25	0.04	0.00	0.41	0.71
Holden		16,221	90	14,599	1.60	110	70	77	lumped w/Res		30	33	17,215	100	17,215	2,616	70	0.18	0.00	0.00	1.6	1.78
Lancaster		6,628	87	5,789	0.55	95	87	83	2	2	11	10	7,478	100	7,478	1,689	70	0.12	0.00	0.00	0.55	0.67
Pepperell		11,756	60	7,002	0.95	136	75	102	17	23	8	11	13,975	80	11,180	4,178	70	0.29	0.10	0.19	0.95	1.53
Shirley	MCI	1,700	100	1,700	0.31	182	13	24	62	113	25	46	1,700	100	1,700	-	70	0.00	0.00	0.00	0.31	0.31
Sterling		7,250	73	5,310	0.51	96	65	62	18	17	17	16	9,290	93	8,640	3,330	62	0.21	0.06	0.02	0.51	0.80
Townsend	TWD	9,500	48	4,529	0.45	99	52	52	26	26	21	21	12,200	62	7,564	3,035	52	0.16	0.08	0.01	0.45	0.70
Townsend	WB	9,500	22	2,088	0.16	77	100	77	0	0	NR		12,200	28	3,416	1,328	70	0.09	0.00	0.00	0.16	0.25
West Boylston		6,965	100	6,965	0.78	112	56	63	11	12	33	37	7,392	100	7,392	427	63	0.03	0.01	0.00	0.78	0.81
Westminster		7,001	74	5,181	0.24	46	60	28	40	19	NR		8,500	94	7,990	2,809	28	0.08	0.05	0.00	0.24	0.37
Worcester		170,163	100	170,163	22.24	131	30	39	53	69	17	22	178,123	100	178,123	7,960	39	0.31	0.55	0.00	22.24	23.10

Notes:
1 - Data taken from most recent ASRs
NR - Data not reported
Holden does not have disaggregated data.

*Column Sb is dependant upon the 10 previous years' growth trends but is calculated from the data that we have now (5 years).

less. For this analysis, Method 1 was used to calculate future demands for all of the communities within the Nashua River Basin, whether or not the above requirements were met. However, the results of the Method 1 calculations were only applied to communities that met the requirements. The results are shown in Table 3-3. The following is a detailed description of the steps contained within Method 1.

Base Population and Base Disaggregated Water Uses (Columns A-L)
The communities that are located in the Nashua River Basin are listed in column A, with the current estimated population (2000) in column B. The base service population percentage (C) and base ADD (E) are taken from the most recent ASRs, along with the available disaggregated data for percent residential ADD (G), percent non-residential ADD (I) and percent UAW ADD (K). These percentages are multiplied by the 2000 base ADD to estimate an ADD for each of the categories (H, J, and L). If the residential ADD is less than 80 GPCD and the UAW ADD percentage is less than 15%, then the respective community is included in Table 3-3, indicating the validity of Method 1.

Future Residential ADD (Columns M-Q)
The population estimates for the year 2020 (M) are extracted from the 2000, 2005, and 2010 population estimates conducted by the Massachusetts Institute for Social and Economic Research (MISER). The percent service population for the year 2020 (N) is estimated as follows:

- It is assumed that if the 2000 percent base service population (C) was 100%, then it would continue to be that in the year 2020.

- In communities where the 2000 percent base service population (C) is 90% or more, it is assumed that it would increase by 5% per decade, to a maximum of 100%.

- For those communities where the 2000 percent base service population (C) is less than 90%, it is assumed that it would increase by 10% per decade, to a maximum of 100%.

- In the instances where two water suppliers are supplying a community, the two service population percentages from each supplier are added together and increased according by the above guidelines, and then reapportioned.

The 2020 service population percent (N) is multiplied by the 2020 population (O) to estimate a 2020 service population (P), which is multiplied by the 2000 residential ADD (H) to estimate a 2020 residential ADD (Q).

Future Non-Residential ADD (Columns R-T)
The increase in non-residential ADD is calculated in two parts (Ra, and Rb). The increase due only to population (Ra) is calculated by multiplying the base non-residential ADD (J) by the service population change (P). If there is a decrease in population over the time period, then this is shown as a negative increase. The

increase due to non-residential ADD trends (Rb) is calculated by using the ASRs from the past ten years from each community. The non-residential ADD from the first three years are averaged and compared to the final three-year average. The trend that is shown is extrapolated to the year 2020. For this analysis there are only five years of ASRs available, so therefore, only the first two years are averaged and compared to the last two-year average, and the trend found is then extrapolated. If a decrease in trend is shown, the non-residential water use is held constant. The total 2020 non-residential ADD (T) is the sum of the increase in non-residential ADD (Ra+Rb) and the 2000 non-residential ADD (S).

Future UAW ADD and Total ADD (Columns U-X)
To estimate the future UAW ADD, it is assumed that if the UAW percentage is less than 10% then this percentage would continue into the future. If the UAW percentage is more than 10% then it is assumed that this would decrease to 10% by 2020. The 2020 UAW ADD (V) is calculated by multiplying the 2020 UAW ADD percentage (U) by the 2000 base ADD (E). Finally, the total 2020 ADD (X) is the sum of the 2020 residential ADD (Q), the 2020 non-residential ADD (T), and the 2020 UAW ADD (V).

Method 2 –Simplified Water Demand Projection

For communities that do not meet the requirements of Method 1, a simplified method, Method 2 can be applied to estimate future water demand. In this analysis, Method 2 is applied to communities meeting the Method 2 requirements, and the results are shown in Table 3-4. The following is a detailed description of the steps contained within Method 2.

Base Population and Base Disaggregated Water Uses (Columns A-L)
These steps are the same as in Method 1.

Future Residential ADD (Columns M-R)
The 2020 population estimates (M), service population percentages (N), service population (O) and the service population change (P) are as calculated in Method 1. The residential ADD factor for the new service population (Q) is equal to the 2000 residential ADD (H), with a maximum of 70 gpcd. If there is no value calculated for the 2000 residential ADD, then the residential ADD factor is assumed to be 70 gpcd. The increase in non-residential ADD (R) is calculated by multiplying the service population change (P) by the residential ADD factor (Q).

Future Non-Residential ADD and Total ADD (Columns S-U)
The 2020 increase in non-residential ADD (Sa and Sb) is as calculated in Method 1, except that in the cases where there is not enough data to calculate the increase, it is assumed to be zero. The total 2020 ADD (U) is the sum of the increase in residential ADD (R), the increase in non-residential ADD (Sa+Sb), and the 2000 base ADD (T).

3.5.2 Comparison and Summary of Water Need Projections

The resulting future 2020 population and water need forecasts, based on the appropriate DEM method, are shown in Table 3-5 for each community. Also shown in Table 3-5 for comparison are population projections and future needs projections as determined in the earlier "Inventory and Analysis of Present and Future Water Needs", Nashua River Basin (DWR, 1989) by the DEM's "Old Water Needs Forecasting Methodology". The results show that the future needs projections remain very similar for many of the Nashua River Basin communities. Many of the changes from the DWR 2020 ADD projections to CDM's 2020 ADD projections are a result of different 2020 population projections and different analysis starting points (2000 ADD).

One of the public water supplies showing a significant change in 2020 ADD is the Boylston Water District. CDM's 2020 ADD prediction is over 100% higher than what DWR predicted. This difference can be attributed to the difference in the population estimate for 2020, where CDM's prediction is 19% higher than what DWR predicted, but more significantly it can be attributed to the difference between the DWR predicted 2000 ADD and CDM's calculated 2000 ADD. CDM's calculated 2000 ADD is 30% higher than what DWR estimated it to be, consequently making CDM's analysis starting point higher than that used in the DWR analysis. Because of this and the increase in the final population estimate, CDM's final 2020 ADD is significantly higher than what DWR estimated. This is similar to what happened to the Groton, Lunenburg, and West Boylston water districts, but to a lesser degree. In addition, there are several communities (e.g., Harvard, Sterling, and Townsend), where CDM had a lower population estimate and a lower starting point (2000 ADD) than DWR, which lead to CDM's significantly lower 2020 ADD estimates.

CDM's 2020 ADD estimate for the West Groton Water District is about 50% lower than what DWR estimated it to be, even though CDM's population estimate for 2020 is higher than the DWR estimate. As shown in the table, CDM's starting point (2000 ADD) is only half of what DWR estimated it to be, therefore making CDM's estimate lower than the DMR estimate. This is similar to what happened in Ayer, where CDM's 2020 population estimate was over 50% higher than DWR's, yet CDM's 2020 ADD is lower than DWR's. Here again, CDM's starting point (2000 ADD) is significantly lower than what DWR estimated it to be. This can also be used to explain the differences found in Westminster and Worcester's 2020 ADD estimates.

As shown in this comparison, the resulting estimates of the analysis are highly dependent upon the population estimates and the current ADDs used. Differences in either the population estimates or the current ADDs may have a compounded effect on the output of the analysis. Much effort has been put forth in this analysis to assure that both the population estimates and the 2000 ADD are current and valid. The 2000 ADD resulting from this analysis was used in the remainder of this report as Existing (2000) ADD.

Table 3-5

Comparison of CDM's ADD Projections to the 1989 DWR ADD Projections

Community	*PWS*	*DWR/OWR 2020 Pop*	*CDM 2020 Pop*	*DWR/OWR Projected 2000 ADD (MGD)*	*CDM's Calculated 2000 ADD (MGD)*	*DWR/OWR 2020 ADD (MGD)*	*CDM 2020 ADD*	
							Method 1 (MGD)	*Method 2 (MGD)*
Ayer		6,495	9,956	1.58	1.08	1.69	1.56	n/a
Boylston	BWD	3,674	4,375	0.23	0.30	0.27	0.74	n/a
Boylston	MWD	3,674	4,375	0.21	0.18	0.25	n/a	0.24
Clinton		12,261	14,423	2.18	2.04	2.36	n/a	2.20
Fitchburg		39,300	37,890	7.02	5.95	7.67	n/a	5.88
Groton	GWD	10,786	13,241	0.30	0.41	0.47	n/a	0.71
Groton	WGWD	10,786	13,241	0.41	0.18	0.71	0.33	n/a
Harvard		9,285	6,550	0.10	0.02	0.31	0.17	n/a
Holden		14,468	17,215	1.21	1.60	1.44	n/a	1.78
Lancaster		6,152	7,478	0.56	0.55	0.64	n/a	0.67
Leominster		36,323	49,300	5.22	4.06	5.83	5.20	n/a
Lunenburg		9,592	11,750	0.37	0.44	0.50	0.66	n/a
Paxton		3,900	4,713	0.30	0.32	0.34	0.42	n/a
Pepperell		15,843	13,975	1.20	0.95	1.80	n/a	1.53
Rutland		5,351	8,200	0.39	0.35	0.58	0.64	n/a
Shirley	MCI	7,834	7,550		0.31		n/a	0.31
Shirley	SDW	7,834	7,550	0.39	0.29	0.65	0.49	n/a
Sterling		11,635	9,290	0.71	0.51	1.23	n/a	0.80
Townsend	TWD	13,515	12,200	0.91	0.45	1.25	n/a	0.70
Townsend	WB	13,515	12,200	0.30	0.16	0.39	n/a	0.25
West Boylston		5,732	7,392	0.57	0.78	0.61	n/a	0.81
Westminster		6,228	8,500	0.33	0.24	0.55	n/a	0.37
Worcester		146,062	178,123	25.65	22.24	27.37	n/a	23.10

n/a: Not applicable

Notes: 1) This table does not imply a discrepancy between current DEM and CDM estimates—it is a comparison of data from a 1989 study with the current study projections.

2) The Division of Water Resources, which developed projections in this table, is now the Office of Water Resources.

3.5.3 Non-Community Water Supply Needs

Table 2-6 summarizes the registered and permitted supply rates for non-community water supplies in the Nashua River Watershed. There are no existing permits for growth in any of the major non-community supplies through the year 2014; therefore, it was assumed that there would be no change in these sources to the year 2020.

3.5.4 MWRA and Worcester Needs

The Massachusetts Water Resources Authority (MWRA) is the largest user of water from the Nashua River Watershed. The MWRA presently limits the discharge from Wachusett Reservoir to 1.8 MGD throughout the year, and it stores the remainder of the flow to meet the demands of MWRA user communities. The present average MWRA withdrawal from Wachusett Reservoir is 148 MGD. In this report, it was assumed that MWRA would continue present practices of management through the year 2020.

Worcester, the second largest user of water from the Nashua River Watershed, uses essentially all of the water from the Quinapoxet River watershed. Although Worcester's total demand is expected to increase from 22.2 MGD in 2000 to 23.1 MGD in 2020, the operations of the reservoir system in the Quinapoxet River watershed are not expected to change. Therefore, increases in demand from that watershed will be reflected as increasing losses of water from that watershed.

3.6 Water Conservation Assessment

This section presents results from a water conservation review for Public Water Suppliers in the Nashua River Watershed. Water use data for Public Water Suppliers were screened using two water conservation "benchmarks" established by the Department of Environmental Management (DEM) Demand Projection Methodology. The screening process and results for each Public Water Supplier are presented in this section. Some background information on Massachusetts Water Conservation Standards is also presented.

3.6.1 Water Conservation Standards

The state standards are presented in Water Conservation Standards for the Commonwealth of Massachusetts (Department of Environmental Management (DEM), Water Resources Commission, June 1994); the seven topics covered by the standards are listed below.

- Public Education
- Leak Detection and Repair
- Metering
- Pricing

- Residential Water Use
- Public Sector Water Use
- Industrial, Commercial and Institutional Water Use

Within each category, the Standards include a number of recommendations. The Standards and recommendations are incorporated into the DEM Water Conservation form described in Section 3.6.2.

3.6.2 DEM Water Conservation Plan for Public Water Suppliers

Public Water Suppliers applying for a Water Management Act permit are required to submit a water conservation plan (WCP) to the DEM. A standard form for a Water Conservation Plan is provided by DEM and must be completed and submitted with the application. This form was recently updated effective July 13, 2000. When the DEP conducts its five-year review for the Nashua Basin, the new form will be sent out to all Public Water Suppliers with a Water Management Act permit. During the five-year review process, all permit conditions are reviewed, including water conservation measures.

3.6.3 Review of Public Water Suppliers

A review of the water conservation plans submitted by public water suppliers yielded information described in this section.

Water Conservation Plan Status

Table 3-6 presents summary information on water conservation plans for all Public Water Suppliers in the Nashua River Watershed, including whether or not they have a WCP on file with DEM, and the date of the WCP. All communities with a Water Management Act permit (10 of 25 Public Water Suppliers) have a WCP on file with DEM, and most of the WCPs are five to six years old.

Many communities do not have a WCP on file with DEP. These communities are registered with DEP but they either do not require a Water Management Act permit, or have applied for a permit and are currently under review. In either case, they are not required to submit a WCP until they require a permit, or their permit application is approved.

Water Ban Status

During the summer of 1999 the DEP Office of Watershed Management sent out a questionnaire to all communities in the Nashua River Watershed, requesting information on the status of water bans in each community (i.e., whether or not a ban was implemented and whether it was voluntary or mandatory). The results of this survey are also included in Table 3-6.

Table 3-6

Water Conservation Assessment

Public Water Supplier	Residential GPCD [1]	Percent UAW [2]	Water Conservation Plan Status		Water Ban Status Summer 1999
			On file with DEP?	Year	
Ayer	65	10	YES	1991	none
Boylston	79	10	YES	1995	none
Boylston, MWD[3]	62	48	N/A[4]	N/A	none
Clinton	111	1	N/A	N/A	none
Devens	no info.	no info.	YES	1998	none
Dunstable	no info.	no info.	N/A	N/A	none
Fitchburg	54	19*	N/A	N/A	none
Gardner	48	33*	N/A	N/A	none
Groton	82	not reported	N/A	N/A	none
Groton WGWSD[5]	48	2	N/A	N/A	none
Harvard	68	10	N/A	N/A	none
Holden	72	30*	YES	1994	none
Lancaster	93	13	YES	1994	none
Leominster	54	9	N/A	N/A	Mandatory
Lunenburg	50	13	YES	1995	none
Paxton	88	4	N/A	N/A	none
Pepperell	102	8	N/A	N/A	Voluntary
Rutland	74	11	YES	1995	Voluntary
Shirley	no info.	6	YES	1994	Mandatory
Sterling	62	17*	YES	1994	Voluntary
Townsend	77	not reported	N/A	N/A	Mandatory
Townsend WB[6]	52	21*	N/A	N/A	Mandatory
West Boylston	63	33*	N/A	N/A	Voluntary
Westminster	46	12	YES	1994	none
Worcester	52	16*	N/A	N/A	Voluntary

Notes:
1) GPCD: Gallons per capita per day
2) UAW: Unaccounted for Water, average from 1994-1998 Annual Statistical Reports
3) MWD: Morningdale Water District
4) N/A: Not applicable- Public Water Supplier does not have a Water Management Act permit or permit is under review, therefore no Water Conservation Plan is required.
5) WGWSD: West Groton Water Supply District
6) WB: Witches Brook
* Explanations of UAW provided by the community in 1998 ASR.

Shaded cells indicate communities that do not meet the water conservation benchmarks specified in the DEM Demand Projection Methodology:

1. Residential GPCD of 80 or less, and
2. Unaccounted for water of 15% or less.

Communities that did not meet these benchmarks were flagged for further evaluation of their water conservation programs.

Stipled cells indicate communities that reported 5 percent UAW or less. These communities were also flagged, based on the assumption that achieving UAW of less than 5% is unlikely.

3.6.4 Screening Methodology

The DEM Water Needs Forecasting Methodology establishes five requirements that must be fulfilled to process a request for a new water needs forecast:

- Water use information based on actual metering for at least the last three years,
- A break-down of water use at least into residential, non-residential, and unaccounted for categories, for the last three years,
- An accurate estimate of service population, both year-round and seasonal, for the last three years,
- Unaccounted-for water must not exceed 15% of the total system water use,
- Residential gallons per capita per day (gpcd) must not exceed 80.

In addition, the water supplier must complete a Water Conservation Plan questionnaire. In this study, communities meeting the following two DEM criteria were assumed to be doing reasonably well:

- Residential Water Use in Gallons per Capita per Day (GPCD) of 80 or less, and
- Unaccounted for water (UAW) of 15 percent or less.

These two metrics were calculated for the Nashua River Watershed community demand projections. For this evaluation, they were used as a general screening tool to evaluate the water conservation programs of Public Water Suppliers in the Nashua River Watershed. Public Water Suppliers that do not meet either of these two standards were flagged. In addition, any PWS reporting five percent UAW or less was also flagged, based on the assumption that achieving UAW of 5% or less is unlikely. Finally, Public Water Suppliers were flagged if they did not report their UAW or if no information was available.

3.6.5 Results of WCP Review

The results of the screening are presented in Table 3-6. Communities that did not meet one or both of the DEM benchmarks are highlighted in the table. The screening found the following results:

- Five Public Water Suppliers exceeded the residential GPCD benchmark of 80,
  - Clinton (111 GPCD)
  - Groton (82 GPCD)
  - Lancaster (93 GPCD)

  - Paxton (88 GPCD)
  - Pepperell (102 GPCD)
- Eight Public Water Suppliers exceeded the UAW benchmark of 15%
  - Boylston – Morningdale Water District (48%)
  - Fitchburg (19%)
  - Gardner (33%)
  - Holden (30%)
  - Sterling (17%)
  - Townsend – Witches Brook (21%)
  - West Boylston (33%)
  - Worcester (16%)
- Seven Public Water Suppliers were flagged because their UAW was either not reported or was reported as 5% or less.

Note that in many cases the cause of high UAW is partially or fully explained in the ASR. The following information is from the 1998 ASR Responses to Question 6- Unaccounted for Water:

<u>Holden (30%):</u> UAW was accounted for in two categories: leaks and meter calibration. Corrective actions to be taken were specified.

<u>Fitchburg (19%):</u> UAW was accounted for in 23 categories including flushing, main breaks, street sweeping, hydrant leaks and a large "low system" leak.

<u>Sterling (17%):</u> UAW was accounted for in three categories: leaks, fire protection and athletic field irrigation. Corrective actions to be taken were specified.

<u>Worcester (16%):</u> Leak reported, estimated at 280 million gallons. Corrective actions to be taken were specified.

<u>Gardner (33%):</u> UAW was accounted for in three categories: leaks, fire protection and cemetery usage during the growing season. Corrective actions to be taken were specified.

<u>West Boylston (33%):</u> UAW was accounted for in two categories: leaks- "heavy due to sewer construction," and flushing program.

<u>Townsend, Witches Brook (21%):</u> UAW was accounted for in four categories: leaks, fire protection, old meters, and large meters. Corrective actions to be taken were specified.

3.6.6 Recommendations

The existing WCPs in many cases are old and may not reflect current conditions in many of the communities. The five-year review should provide updated information using the new WCP form, which will also provide more information. A review of the new WCP for the communities flagged in the above screening is recommended to be performed.

Section 4
Water Supplies at Risk

4.1 General

This section presents the evaluation to identify public water supplies in the Nashua River Basin that are in proximity to either Massachusetts Contingency Plan (MCP) sites or solid waste facilities. The Massachusetts Contingency Plan 310 CMR 40.0 regulates releases of oil and/or hazardous materials to the environment. The methodology developed for this analysis identifies "Sites of Potential Concern", and "Supplies Potentially at Risk." Sites of Potential Concern (SPCs) are MCP and solid waste sites that are either within a state-designated protection area for a public water supply (surface water and wellhead protection zones), or within 5,000 feet of a public water supply.

MCP and Solid Waste Sites were further screened to assess the level of potential risk they pose, using the following three categories:

- Category 1: the site is likely to pose a potential risk,
- Category 2: the site may pose a potential risk, or
- Category 3: the site is not likely to pose a potential risk.

Screening criteria for sites are presented in Section 4.2. The Nashua Basin contains the following:

- 143 Public Water Supplies - all have state-designated protection zones.
- 153 MCP Sites
- 29 Solid Waste Sites

4.2 Methodology

Data used for this evaluation were obtained from several Mass GIS coverages. Following is a description of each datalayer, including coverage definition, the coverage date, and data source for each coverage. There are several important caveats that apply to all GIS coverages used in this analysis:

- Data represented in each coverage are dynamic- sites are continuously being added and removed; however, the coverage is static and presents only a snapshot in time.
- Coverages are updated on a somewhat regular basis. Update dates for coverages used in this analysis are provided with the coverage descriptions below.

4.2.1 MCP Site Coverage

MCP is implemented by DEP Bureau of Waste Site Cleanup (BWSC). The MCP site coverage was most recently updated in October 2000. The coverages in this datalayer are defined as follows:

- **Site Classification**: Following one year of discovery, if not resolved, sites are usually Tier Classified using the Numerical Ranking System (NRS). The NRS scores sites on a point system based on a variety of factors. These include the site's complexity, the type of contamination, and the potential for human or environmental exposure to the contamination. In addition, some sites are automatically classified as Tier I sites if they 1) pose an imminent hazard to human health or environmental receptors 2) are located in a public water supply Zone II and have contaminant concentrations exceeding a defined threshold, or 3) miss regulatory deadlines. Following are the five Tier classes:

- **Tier IA**: A site/release receiving a total NRS score equal to or greater than 550.

- **Tier IB**: A site/release receiving a total NRS score less than 550 and equal to or greater than 450.

- **Tier IC**: A site/release receiving a total NRS score less than 450 and equal to or greater than 350.

- **Default Tier IB**: A site/release where the responsible party fails to provide a Tier Classification to DEP within one year of discovery.

- **Tier II**: A site/release receiving a total NRS score of less than 350, unless the site meets any of the Tier I Inclusionary Criteria.

4.2.2 Solid Waste Site Coverage

The Solid Waste Site Coverage was most recently updated in February 1997. The 1997 coverage was updated for this analysis based on information provided by the MA Department of Environmental Protection, Central Region Office (DEP CERO) (Purna Rao, personal communication, February 2000). Note also that although the coverage is now three years old, no new landfills are expected.

The solid waste datalayer was compiled by the DEP to track landfills, transfer stations, and combustion facilities. The datalayer contains the majority of the facilities currently regulated under DEP's solid waste regulations (310 CMR 16.00 & 19.00) but does not contain all solid waste facilities known to DEP. The MassGIS land-use datalayer has waste site classifications that may represent landfills not in the solid waste datalayer. Data from the land use coverage were not included in this analysis.

4.2.3 Public Water Supply Coverage

The MassGIS Public Water Supply (PWS) datalayer was most recently updated in August 2000. It contains public community surface and groundwater supplies, as defined in 310 CMR 22.00, the Massachusetts Drinking Water Regulations, and 1528 public non-community sources (MassGIS, 2000). The coverages in this datalayer are defined as follows:

- **Community Water Supply**: part of a community water system, which serves at least 15 service connections used by year-round residents or regularly serve at least 25 year-round residents.

- **Non-Community Water Supply**: a single service connection that is potentially available to 25 or more persons, such as a school, factory, or restaurant. Non-Community Water Supplies are further defined as being Transient or Non-Transient based on the usage period, with less than 6 months use on a yearly basis being considered Transient.

Surface Water Supply Protection Areas

The MassGIS Surface Water Supply Protection datalayer was most recently updated in August 2000. It delineates those areas included in 310 CMR 22.00 as Surface Water Supply Protection Zones, which are defined as follows:

- **Zone A**: represents a) the land area between the surface water source and the upper boundary of the bank; b) the land area within a 400 foot lateral distance from the upper boundary of the bank of a Class A surface water source, as defined in 314 CMR 4.05(3)(a); and c) the land area within a 200 foot lateral distance from the upper boundary of the bank of a tributary or associated surface water body.

- **Zone B**: represents the land area within one-half mile of the upper boundary of the bank of a Class A surface water source, as defined in 314 CMR 4.05(3)(a), or edge of watershed, whichever is less. Zone B always includes the land area within a 400-foot lateral distance from the upper boundary of the bank of the Class A surface water source.

- **Zone C**: represents the land area not designated as Zone A or B within the watershed of a Class A surface water source, as defined in 314 CMR 4.05(3)(a).

- **Watershed Protection Act Regulations**: These apply to the Wachusett Reservoir and Worcester's water supply reservoirs in the Wachusett watershed.

Ground Water Supply Protection Areas

The MassGIS coverage for DEP Wellhead Protection Areas (Zone IIs and Interim Wellhead Protection Areas (IWPAs)) was most recently updated in October 2000. The coverages in this datalayer are defined as follows:

- **Zone II**: A wellhead protection area that has been determined by hydrogeologic modeling and approved by the DEP Drinking Water Program (DWP).

- **IWPA**: In cases where hydro-geologic modeling studies have not been performed and there is no approved Zone II, an Interim Wellhead Protection Area is established based on DEP DWP well pumping rates or default values. The formula used for calculating the IWPA is Radius = (32 x pumping rate in GPM)+ 400. The minimum IWPA radius is 400 feet; the maximum (default) radius reached at 100,000 GPD (70 GPM) is 2,640 feet (1/2 mile).

- **Default Zones**: In instances where DWP pumping rate information is unavailable, DWP approved default radius values are assigned based on PWS well classification. The default radiuses are as follows:

  - 2,640 feet for community class PWS groundwater sources,
  - 750 feet for Non Transient (NTNC) wells, and
  - 500 feet for Transient (TNC) wells.

4.3 Evaluation Methodology

GIS analysis was used to identify Public Water Supplies (PWS) that may be at risk due to their proximity to MCP sites or solid waste facilities. The analysis was performed by intersecting several datalayers and extracting subsets using proximity criteria as follows:

- The GIS coverages for Public Water Supplies and their protection areas (Zone A and B for surface water, and Zone II and IWPA for ground water) were overlaid with the MCP Site and Solid Waste Site coverages.

- All MCP sites and solid waste sites located within any of the protection areas or within 5,000 feet or less of a PWS were extracted as a subset and identified as "**Sites of Potential Concern**", or SPCs.

4.3.1 Criteria for Assessing Potential Risk to Public Water Supplies

To further assess risk, SPCs were screened and prioritized by likelihood of the risk they may pose to Public Water Supplies. The goal of these additional categories is to differentiate the levels of risk posed by each site so resources can be focused on sites that are likely to pose the greatest risks. The following three categories were developed to describe the likelihood that a MCP or Solid Waste SPC poses a potential risk to a Public Water Supply:

Category 1: The site **is Likely to Pose a Potential Risk**

Category 2: The site **May Pose a Potential Risk**

Category 3: The site **is Not Likely to Pose a Potential Risk**

Criteria for MCP Sites

Categorization of MCP SPCs was based on the following factors:

- Tier designation in the MCP, and
- Distance from the MCP site to the PWS.

Category 1 - Likely to Pose a Potential Risk - MCP Sites: Category 1 includes Tier IA, Tier IB, Tier IC, and Default Tier IB sites that are within the state-designated protection area of a PWS. <u>Sixteen MCP sites are in this category</u>.

Category 2 - May Pose a Potential Risk - MCP Sites: Category 2 includes Tier II sites that are with the state-designated protection area of a PWS. <u>Three MCP sites are in this category.</u>

Category 3 – Not Likely to Pose a Potential Risk - MCP Sites: Category 3 includes Tier IA, Tier IB, Tier IC, and Default Tier IB sites that are outside the state-designated protection area of a PWS, but within 5,000 feet of a PWS. <u>Twenty MCP sites are in this category</u>

Note that site-specific knowledge, when available, should be factored into the screening process and may result in a different categorization. For example, several sites within the Wachusett Subbasin are listed as Tier IA but are far along in the clean up process and should be reclassified as Tier II in the near future.

Criteria for Solid Waste Sites

Categorization of Solid Waste SPCs was based on the following three factors:

- Closure status of the site (i.e., whether it is lined and/or capped);
- Distance from the site to the PWS.

Category 1 – Likely to Pose a Potential Risk - Solid Waste Sites: Category 1 includes any solid waste site (active or inactive) that is unlined and uncapped, or any site for which the liner or cap status in unknown that is within a state-designated protection areas of a PWS. <u>Two Solid Waste sites are in this category.</u>

Category 2 – May Pose a Potential Risk - Solid Waste Sites: Category 2 includes any solid waste site that is capped but not lined, or lined but not capped that is within a state-designated protection areas of a PWS. <u>No solid waste sites are in this category.</u>

Category 3 – Not Likely to Pose a Potential Risk - Solid Waste Sites: Category 3 includes any solid waste site that is outside a state-designated protection area, but within 5,000 feet of a PWS. <u>No solid waste sites are in this category.</u>

Again, site-specific knowledge, when available, should be factored into the screening process and may change the result.

4.4 Findings

The findings of the analysis will be presented and discussed.

4.4.1 Public Water Supplies

Table 4-1 presents summary information on the Public Water Supplies in the Nashua River Basin that is contained in the MassGIS datalayer. There are 143 supplies, including:

- 62 Community Groundwater Supplies (GW),
- 24 Community Surface Water Supplies (SW),
- 39 Transient Non-Community Supplies (TNC), and
- 18 Non-Transient Non Community Supplies (NTNC).

All 24 Surface Water Supplies have associated Zone A and B Protection Areas. Only 23 of the 62 Groundwater Supplies have Zone IIs; the remaining 39 have IWPAs. Only one TNC supply has a Zone II- the remaining 38, and all 18 NTNC supplies have IWPAs. The lack of Zone II delineation for many of the groundwater supplies influences this assessment. Zone IIs tend to be larger than IWPAs and more accurately reflect the zone of influence around a wellhead. There may be MCP or Solid Waste Sites that are not within the IWPA of a supply but would be within its Zone II. To reduce the risk of missing these sites, we added a category to identify any PWS within 5,000 feet or less (just under a mile) of a MCP or Solid Waste Site.

4.4.2 MCP Sites

Tables 4-2 and 4-3 present summary information on MCP SPCs in the Nashua River Watershed. Table 4-2 provides summary information including the number of MCP sites in the basin, number within the different protection areas or 5,000 feet of a PWS. Table 4-3 lists each MCP site and gives its tier status, type of contamination, the name of the PWS in proximity to the site, and an assessment of the risk posed to the PWS. Key information from Tables 4-2 and 4-3 is highlighted below:

- There are 153 MCP Sites in the MassGIS Nashua River Basin coverage. Nineteen of the MCP sites are within the state-designated protection areas for a PWS. Thirty-nine of these sites are within 5,000 feet of a public water supply.

Table 4-1

Summary Information on Protection Areas for Public Water Supplies

Public Water Supply Type [1]	*Number of Public Water Supplies in the Nashua Basin* [1]	*Supplies with a Zone II* [2]	*Supplies with an IWPA* [3]	*Supplies with a Zone A and B* [4]	*Percent of Supplies with a Protection Zone* [5]
Ground Water (GW)	62	23	39	N/A	100%
Surface Water (SW)	24	N/A	N/A	24	100%
Transient Non-Community (TNC)	39	1	38	N/A	100%
Non-Transient Non-Community (NTNC)	18	0	18	N/A	100%
TOTALS:	143	24	95	24	

Notes:

1) From Mass GIS Public Water Supply Coverage, updated August 2000. Data are from the MA DEP Drinking Water Program (DWP). Regulated Public Water Supplies are categorized as follows:

GW = groundwater source, public

SW = surface water source, public

TNC = Transient Non-Community source

NTNC = Non-transient non-community source

2) A Zone II is a wellhead protection area that has been determined by hydrogeologic modeling and approved by the DEM's

3) IWPA= Interim Wellhead Protection Area. In cases where hydrogeologic modeling studies have not been performed and there is no approved Zone II, an IWPA is established based on DEP DWP well pumping rates or default values.

4) Zone A represents a) the land area between a surface water source and the upper boundary of the bank; b) the land area within a 400 foot lateral distance from the upper boundary of the bank of a Class A surface water source; and c) the land area within a 200 foot lateral distance from the upper boundary of the bank of a tributary or associated surface water body.

5) Percent of all DEP regulated Public Water Supplies in the Nashua Basin that have an associated protection zone.

Table 4- 2

Summary of MCP Site Data

MCP Site Compliance Status [1]	*Total Number of MCP Sites*		*Number of Sites Within*	
	In the Nashua River Basin	*In Proximity to a PWS* [2]	*State-Designated Protection Area* [3]	*Within 5000 ft of PWS* [4]
Tier IA	9	6	3	3
Tier IB	11	6	5	1
Tier IC	18	16	5	11
Default Tier IB	29	8	3	5
Tier II	86	3	3	0
Totals	153	39	19	20

Notes:

1) Data are from MassGIS coverage for MCP sites (October, 2000). Following are definitions of each compliance status from the MA DEP Bureau of Waste Site Cleanup.

Sites are usually Tier Classified using the Numerical Ranking System (NRS). The NRS scores sites on a point system based on a variety of factors. These include the site's complexity, the type of contamination, and the potential for human or environmental exposure to the contamination. In addition, some sites are automatically classified as Tier I sites if they 1) pose an imminent hazard, 2) are located within a Zone II of a public water supply or 3) miss regulatory deadlines.

Tier IA: A site/release receiving a total NRS score equal to or greater than 550.

Tier IB: A site/release receiving a total NRS score less than 550 and equal to or greater than 450.

Tier IC: A site/release receiving a total NRS score less than 450 and equal to or greater than 350.

Default Tier IB: A site/release where the responsible party fails to provide a Tier Classification to DEP within one year of site discovery

Tier II: A site/release receiving a total NRS score of less than 350, unless the site meets any of the Tier I Inclusionary Criteria.

2) PWS= A Public Water Supply that is regulated by MA DEP Drinking Water Program (DWP), see Table 1.

3) State-Designated Protection Area includes Zone II, IWPA, Zone A, Zone B

4) This category was included to provide an additional measure of proximity for protection areas with a radius less than 2,000 feet.

Table 4-3

MCP Sites and Associated Public Water Supply Sources

MCP Site	*RTN*	*TOWN*	*Status*	*Type*[1]	*Cat. 1*	*Cat. 2*	*Cat. 3*	*Water Supply*	*Public Water Supply Owner*
COMMERCE BANK	2-0012418	WEST BOYLSTON	TIER II	OHM		X		GP Well #5, Pleaseant Valley	West Boylston
DURANT REALTY TRUST PROPERTY	2-0011096	HOLDEN	TIER IC	HM	X			Quinapoxet River 2 GP Wells	Holden
SEABOARD FOLDING BOX CORP	2-0010394	FITCHBURG	TIER IC	O			X	Overlook Reservoir	Fitchburg
A&E FORKLIFT CO	2-0000486	ASHBY	DEF TIER IB	OHM			X	Country Creamery Willard Brook State Forest Evergreen Family Restaurant	 DEM
FORT DEVENS	2-0000662	AYER	TIER IA	OHM	X			MacPherson Naturally Developed Well	Ayer
SHELL STATION FMR	2-0010827	AYER	TIER IC	O	X			MacPherson Naturally Developed Well	Ayer
MOLUMCO IND PARK PLASTICS DISTR CTR	2-0010138	AYER	TIER IA	HM			X	The Appleworks Grove Pond GP Wells Grove Pond Well #1 Grove Pond Well #2	 Ayer Ayer Ayer
ICE HOUSE DAM	2-0011873	AYER	TIER IC	O	X			MacPherson Naturally Developed Well Patterson Road GP Well Cross Street GP Well #2	Ayer Shirley Townsend
PRINCETON STORE	2-0000951	PRINCETON	DEF TIER IB	O	X			Princeton Marketplace & Pizza	
REISNER CORP	2-0001009	CLINTON	TIER IC	HM	X			GP Well #1 GP Well #2 The International Inc.	Lancaster Lancaster
NO LOCATION AID	2-0012360	FITCHBURG	TIER IC	O			X	Overlook Reservoir	Fitchburg
SAGE DEVELOPMENT CORP	2-0000119	SHIRLEY	TIER IA	OHM			X	Shirley Garage Inc./Airport Diner Catacoonamug Road GP Well	 Shirley
MCI SHIRLEY	2-0012181	SHIRLEY	TIER IC	O			X	Shirley Garage Inc./Airport Diner GP Well #1 GP Well #2	 Lancaster Lancaster
MCI SHIRLEY	2-0012035	SHIRLEY	TIER IC	O			X	Shirley Garage Inc./Airport Diner GP Well #1 GP Well #2	 Lancaster Lancaster
MCI SHIRLEY DEPT OF CORRECTION	2-0000993	SHIRLEY	TIER IC	O			X	Shirley Garage Inc./Airport Diner GP Well #1 GP Well #2	 Lancaster Lancaster
PETERBOROUGH OIL CO	2-0000011	ASHBY	TIER IA	O			X	Ashby Elementary School	
SPEEDWAY PETROLEUM	2-0000702	FITCHBURG	TIER IC	O			X	Simonds Pond Reservoir	Leominster
PUBLIC SAFETY BLDG	2-0012647	PRINCETON	TIER IB	OHM	X			First Conggregation Church of Princeton Princeton Marketplace & Pizza	
PUBLIC SAFETY BLDG	2-0011791	PRINCETON	TIER IB	O	X			First Congregation Church of Princeton Princeton Marketplace & Pizza	
LORDEN OIL CO	2-0012461	TOWNSEND	TIER IC	O			X	Cross Street GP Well #2	Townsend
PRATTS JUNCTION SUBSTATION	2-0012349	STERLING	TIER II	OHM		X		S.E. Well #160 S.E. Well 120 S.E. Well #110	Leominster Leominster Leominster

Table 4-3 (cont)

MCP Sites and Associated Public Water Supply Sites

MCP Site	*RTN*	*TOWN*	*Status*	*Type*[1]	*Cat. 1*	*Cat. 2*	*Cat. 3*	*Water Supply*	*Public Water Supply Owner*
PUBLIC SAFETY BUILDING	2-0011327	PRINCETON	TIER IB	OHM	X			First Congregation Church of Princeton Princeton Marketplace & Pizza	
CUMBERLAND FARMS	2-0011952	LANCASTER	TIER IA	O	X			GP Well #1 GP Well #2	Lancaster Lancaster
LANCASTER COMPLEX	2-0012558	LANCASTER	TIER IC	O	X			GP Well #1 GP Well #2	Lancaster Lancaster
WHEETABIX CORP	2-0012515	CLINTON	TIER II	O		X		The International Inc. GP Well #1 GP Well #2	 Lancaster Lancaster
BOSTON GAS PROPERTY	2-0011168	CLINTON	DEF TIER IB	O			X	Wachusett Reservoir	MWRA
WACHUSETT RESERVOIR GATE 39	2-0012644	CLINTON	TIER IB	O	X			Wachusett Reservoir	MWRA
LEOMINSTER PUMPING STATION	2-0001039	CLINTON	TIER IB	O	X			Wachusett Reservoir	MWRA
LANCASTER TOWN OF DPW HIGHWAY BARN	2-0012557	LANCASTER	TIER IC	O			X	GP Well #1 GP Well #2	Lancaster Lancaster
LANCASTER TOWN OF DPW HIGHWAY BARN	2-0012556	LANCASTER	TIER IC	NO DATA			X	GP Well #1 GP Well #2	Lancaster Lancaster
SHELL OIL	2-0000146	WEST BOYLSTON	TIER IA	O	X			Wachusett Reservoir	MWRA
MR MIKES CITGO	2-0000642	AYER	TIER IC	O			X	Grove Pond GP Wells Grove Pond Well #1 Grove Pond Well #2 The Appleworks Epic Enterprises, Inc. Harvard Plaza	Ayer Ayer Ayer
DURANT REALTY TRUST	2-0012779	HOLDEN	DEF TIER IB	HM	X			Quipoxet River GP Wells	Holden
SEABOARD FOLDING BOX CORP	2-0011395	FITCHBURG	TIER IC	HM			X	Overlook Reservoir	Fitchburg
TAVERAS FAMILY TRUST	2-0013077	HARVARD	DEF TIER IB	OHM			X	The Appleworks Harvard Plaza Concord Hillside Medical Assoc. Rock Well #1, Foxglove Apts. GP Well #1, Harvard Green Condo GP Well #2, Harvard Green Condo	
ERNST & TAVERAS PROPERTY FMR	2-0010067	HARVARD	TIER IB	O			X	The Appleworks Harvard Plaza Concord Hillside Medical Assoc. Rock Well #1, Foxglove Apts. GP Well #1, Harvard Green Condo GP Well #2, Harvard Green Condo	
NO LOCATION AID	2-0011050	TOWNSEND	DEF TIER IB	O			X	Cross Street GP Well #2	Townsend
HAWTHORNE BROOK SCHOOL	2-0012919	TOWNSEND	DEF TIER IB	NO DATA	X			Cross Street GP Well #2	Townsend
ART PRODUCTS	2-0000828	FITCHBURG	DEF TIER IB	O			X	Overlook Reservoir	Fitchburg

Notes:

1)Type indicates contaminant type includes Oil (O) and Hazardous Materials (HM)
2) Category type refer to Section 4.3 for definition

- There are 16 **Category 1** Sites (i.e., sites likely to pose a potential risk); 25 water supplies are in their proximity, 13 of these are community supplies.
- There are 3 **Category 2** Sites (i.e., sites that may pose a potential risk); 7 supplies are in their proximity, 6 of these are community supplies.
- There are 20 **Category 3** Sites (i.e., sites that are not likely to pose a potential risk); 25 water supplies are in their proximity, 11 of these are community supplies.

4.4.3 Solid Waste Facilities

Tables 4-4 and 4-5 present summary information on Solid Waste SPCs in the Nashua River Watershed. Table 4-4 provides information on the public water supplies that are in proximity to solid waste sites. Table 4-5 describes the solid waste sites and provides an assessment of the risk they may pose to public water supplies. Key information from both tables is highlighted below:

- There are 29 Solid Waste Sites in the MassGIS Nashua River Basin coverage. Two of these sites are SPCs.
- There are 2 **Category 1** Sites; 4 water supplies are in their proximity, all 4 are community supplies.
- There are no **Category 2** Sites.
- There are no **Category 3** Sites.

4.4.4 Supplies Potentially at Risk

Category 1 sites are likely to pose the greatest potential risk to Public Water Supplies. Table 4-6 presents the community water supplies at risk from MCP and / or Solid Waste sites in the Nashua River watershed. Figure 4-1 presents the location of the public water supplies potentially at risk from MCP sites, and Figure 4-2 presents the location of the public water supplies potentially at risk from solid waste sites. The following community supplies are defined to be in Category 1, (Likely to pose a potential risk)

Community Supplies

- Ayer, Grove Pond Well #1 and #2
- Holden, Quinapoxit River GP Wells
- Shirley, Patterson Road GP Well,
- Townsend, Cross Street GP Well #2
- Lancaster, GP Well #1 and #2

- MWRA / Wachusett Reservoir

Table 4-7 presents the non-community water supplies at risk from MCP and / or Solid Waste Sites. The following three sources are defined to be in Category 1, (Likely to pose a potential risk)

Non-Community Supplies

- First Congregation Church of Princeton
- The International, Inc. (golf course, Bolton)
- Princeton Marketplace & Pizza

Table 4-4

Solid Waste Sites and Associated Public Water Supply Sources

SOLID WASTE SITE NAME [1]	TOWN	SITE IS WITHIN					NAME OF PWS IN PROXIMITY TO SOLID WASTE SITE	TYPE OF PWS [2]	CATEGORY [3]
		ZONE A [2]	ZONE B [2]	ZONE II [2]	IWPA [2]				
AYER DEMOLITION LANDFILL	AYER	NO	NO	***YES***	NO		GROVE POND WELLS #1 & #2, Ayer	GW	1
LANCASTER LANDFILL	LANCASTER	NO	NO	NO	***YES***		Gravel Pack WELL #1 and# 2, Lancaster	GW	1

Notes:
1) Data are from Mass GIS Solid Waste Site coverage from February 1997, updated by review from DEP Solid Waste Division (Purna Rao, March and June 2000)
2) See Table 4-1 for definitions of protection zones and public water supply types.
3) Categories represent the likelihood that a Solid Waste Site poses a potential risk to a PWS and are defined as follows:
   Category 1: The site is Likely to Pose a Potential Risk
   Category 2: The site May Pose a Potential Risk
   Category 3: The site is Not Likely to Pose a Potential Risk

Table 4-5

Status of Solid Waste Facilities

SOLID WASTE SITE NAME	*OWNER*	*TOWN*	*ACRES*[1]	*USE STATUS*[1]	*CAP STATUS*[1]	*LINER STATUS*[1]	*CATEGORY*[2]
AYER DEMOLITION LANDFILL	*NOT LISTED*	AYER	3.6	Inactive	Unknown Cap	Not Lined	1
LANCASTER LANDFILL	TOWN OF LANCASTER	LANCASTER	29.7	Inactive	Unknown cap	Not Lined	1

NOTES:
1) Data are from MassGIS Solid Waste Site coverage from February 1997, updated by review from DEP Solid Waste Division (Purna Rao, March and June 2000)
2) Categories represent the likelihood that a Solid Waste Site poses a potential risk to a PWS and are defined as follows:
Category 1: The site is Likely to Pose a Potential Risk
Category 2: The site May Pose a Potential Risk
Category 3: The site is Not Likely to Pose a Potential Risk

Table 4-6

Potential Loss of Community Water Supply

Town	Percent of Community Supply (%)	Average Daily Withdrawal (mgd)	Source ID	Source Name	MCP Sites			Solid Waste Sites		
					Cat. 1	Cat. 2	Cat. 3	Cat.1	Cat. 2	Cat. 3
AYER	3.4%	0.041	2019000-02G	GROVE POND WELL # 2			X	X		
AYER	7.2%	0.087	2019000-01G	GROVE POND WELL # 1			X	X		
AYER	40.7%	0.492	2019001-04G	GROVE POND GP (12 8") WELLS			X			
AYER	48.7%	0.589	2019001-03G	MACPHERSON NATURALLY DEVELOPED WELL			X			
Subtotal	100.0%	1.209								
FITCHBURG	5.5%	0.403	2097000-07S	OVERLOOK RESERVOIR			X			
HOLDEN	36.5%	0.499	2134000-02G	QUINAPOXET RIVER GP WELLS (2)	X					
LANCASTER	45.7%	0.253	2147000-01G	GP WELL # 1			X	X		
LANCASTER	54.3%	0.301	2147000-02G	GP WELL # 2			X	X		
Subtotal	100.0%	0.554								
LEOMINSTER	0.0%	0.000	2153000-05G	S.E. WELL #160, S.E. CORNER		X				
LEOMINSTER	2.4%	0.176	2153000-02S	SIMONDS POND RESERVOIR			X			
LEOMINSTER	3.2%	0.213	2153000-04G	S.E. WELL #120, S.E. CORNER		X				
LEOMINSTER	4.5%	0.301	2153000-03G	S.E. WELL #110, S.E. CORNER		X				
Subtotal	10.1%	0.690								
SHIRLEY	0.0%	0.000	2270001-01G	GP WELL # 1			X			
SHIRLEY	21.2%	0.062	2270000-02G	CATACUNEMAUG ROAD GP WELL			X			
SHIRLEY	78.8%	0.230	2270000-03G	PATTERSON ROAD GP WELL	X					
Subtotal	100.0%	0.292								
TOWNSEND	41.9%	0.177	2299000-02G	CROSS STREET GP WELL #2	X		X			
WEST BOYLSTON	22.6%	0.147	2321000-05G	GP WELL #5, PLEASANT VALLEY		X				
CLINTON			2064000-01P	MWRA SUPPLY / WACHUSETT RESERVOIR	X		X			

Notes:

(shaded) Water supplies with a Category 1 MCP Site or Solid Waste Site within the state-designated protection area.

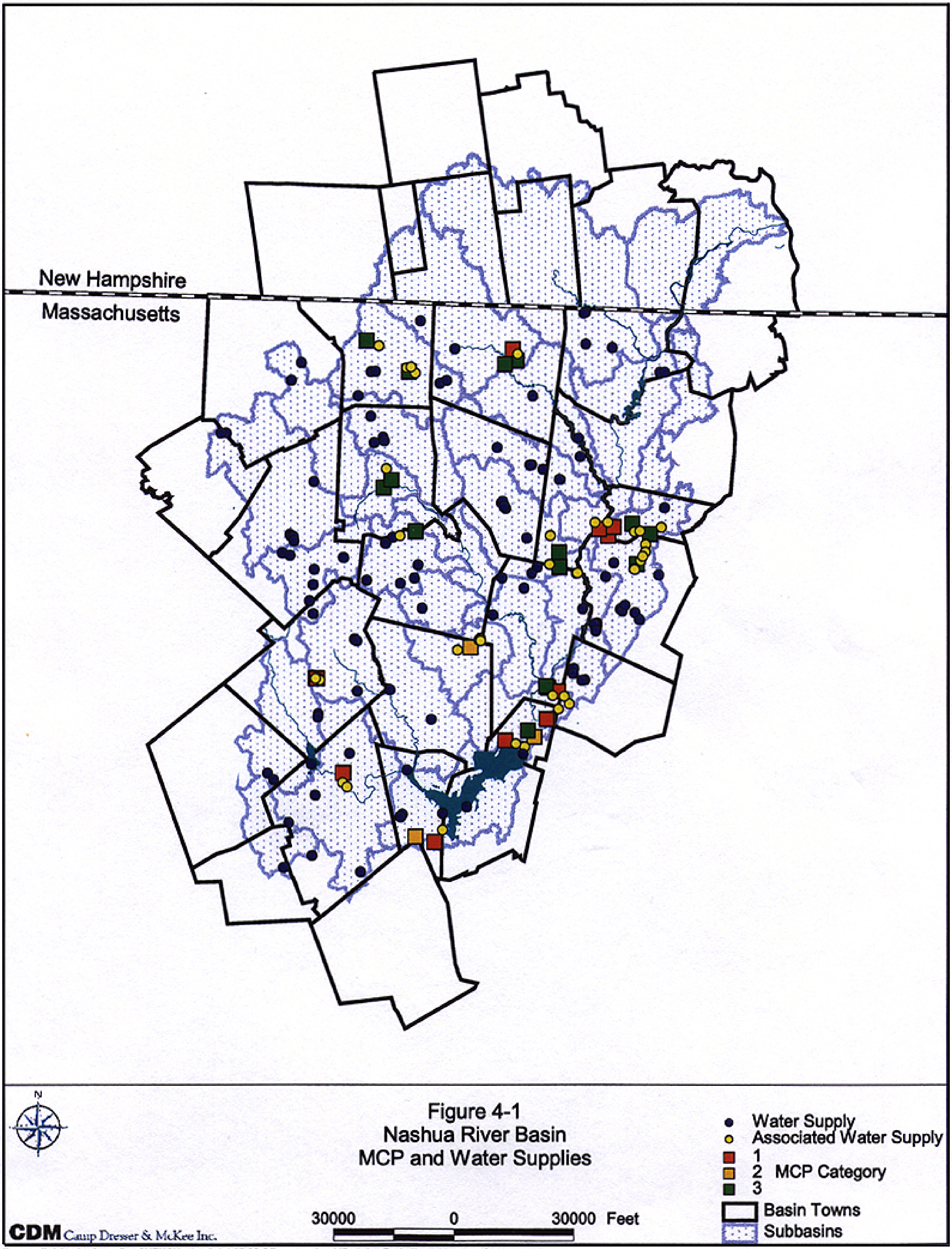


Figure 4-1
Nashua River Basin
MCP and Water Supplies

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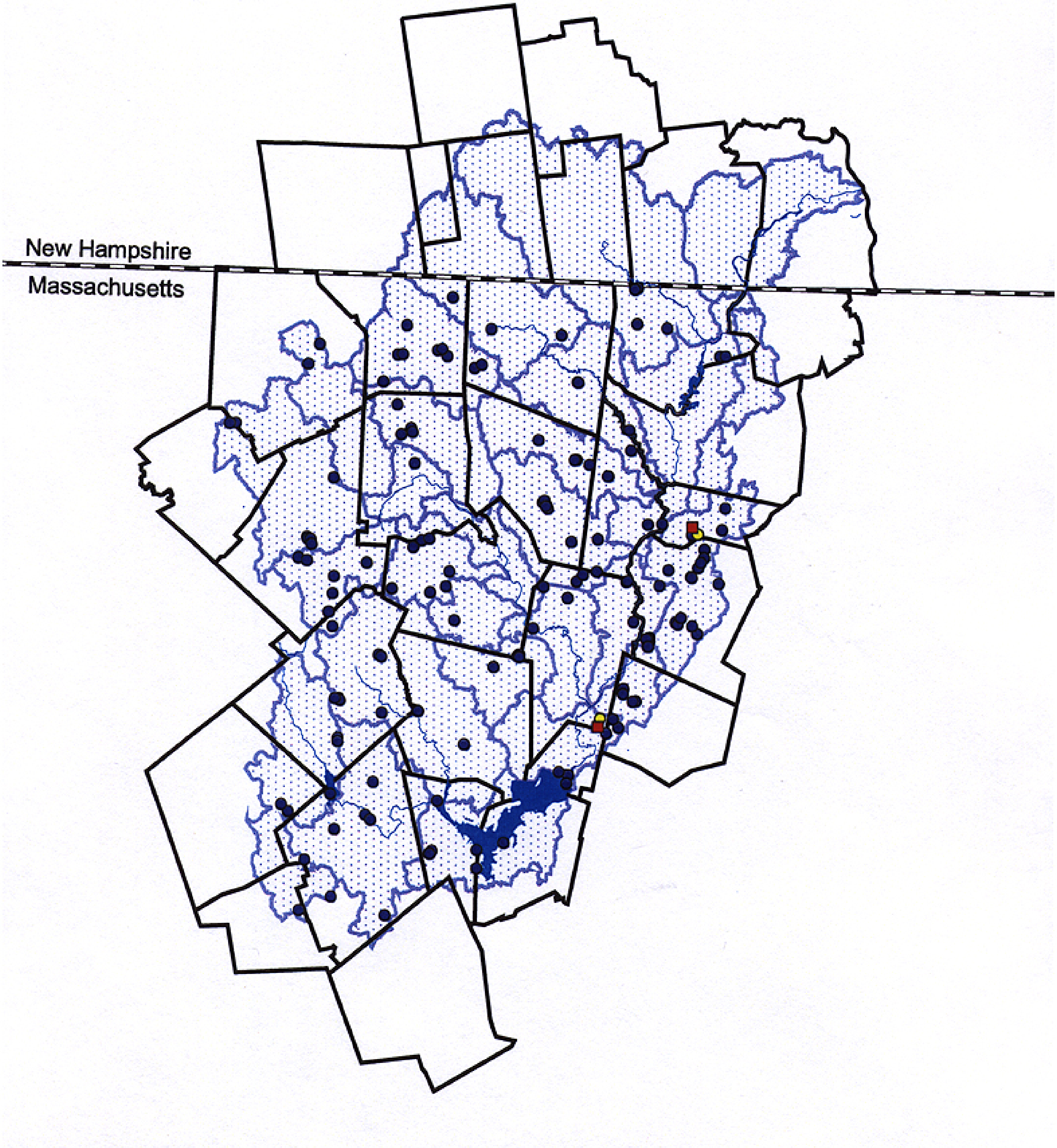

Figure 4-2
Nashua River Basin
Solid Waste and Water Supplies

Water Supply
Associated Water Supply
1 Solid Waste
2 Category
3
Basin Towns
Subbasins

30000 0 30000 Feet

CDM

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Table 4-7

Potential Loss of Non-Community Water Supply

Town	Percent of Community Supply (%)	Average Daily Withdrawal (mgd)	Source ID	Source Name	MCP Sites			Solid Waste Sites		
					Cat. 1	Cat. 2	Cat. 3	Cat.1	Cat. 2	Cat. 3
PRINCETON	N/A	N/A	2241006-01G	FIRST CONGREGATION CHURCH OF PRINCETON	X					
SHIRLEY	N/A	N/A	2270003-01G	SHIRLEY GARAGE INC./AIRPORT DINER			X			
HARVARD	N/A	N/A	2125007-01G	THE APPLEWORKS			X			
AYER	N/A	N/A	2019005-01G	EPIC ENTERPRISES, INC.			X			
ASHBY	N/A	N/A	2012003-01G	COUNTRY CREAMERY			X			
ASHBY	N/A	N/A	2299002-01G	DEM WILLARD BROOK STATE FOREST			X			
BOLTON	N/A	N/A	2034004-05G	THE INTERNATIONAL, INCORPORATED	X					
HARVARD	N/A	N/A	2125010-01G	HARVARD PLAZA			X			
HARVARD	N/A	N/A	2125012-01G	CONCORD HILLSIDE MED. ASSOC./GAIA HERBS			X			
HARVARD	N/A	N/A	2125013-01G	ROCK WELL #1, Foxglove Apts.			X			
ASHBY	N/A	N/A	2012004-01G	EVERGREEN FAMILY RESTAURANT			X			
HARVARD	N/A	N/A	2125014-01G	WELL #1, Harvard Green Condo			X			
HARVARD	N/A	N/A	2125014-02G	WELL #2, Harvard Green Condo			X			
PRINCETON	N/A	N/A	2241016-01G	PRINCETON MARKETPLACE & PIZZA	X					
ASHBY	N/A	N/A	2012002-01G	ASHBY ELEMENTARY SCHOOL			X			

Notes:

Water supplies with a Category 1 MCP Site or Solid Waste Site within the state-designated protection area.

Section 5
Wastewater Discharges

5.1 General

This section presents current average (1997-98) values and estimates of the future (through 2020) wastewater generation for communities that discharge their wastewater in the Nashua River Watershed. Industrial discharges were assumed to remain at their present levels. The communities are identified in Section 5.2. The existing sewer service areas for each of these communities are presented in Section 5.3. In communities where plans for improvements and expansions to the existing sewer system have already commenced, planned future service areas are presented in Section 5.4. Growth in wastewater generation was generally assumed proportional to the growth in water demand. Details of the methodology for calculating future wastewater needs are given in Section 5.5.

5.2 Watershed Communities

Current and future wastewater needs projections were developed for all communities within the Nashua River Watershed as well as communities outside the watershed that collect wastewater from within the watershed. Only communities with sewer collection systems were considered in this analysis. Title 5 communities (septic systems) do not discharge or collect wastewater beyond the immediate vicinity of each septic system. Table 5-1 summarizes the existing wastewater service information, including the wastewater disposal status (Title 5 or sewer), the method of determining the amount of wastewater collected from each community (see Section 5.3), as well as the river basins to which each system discharges water.

5.3 Present Service Areas

Existing wastewater service areas were required to distribute known wastewater flows between the subareas contained within each municipality in an appropriate manner. Service areas were determined using one of three possible methods:

- **Available GIS Coverage:** If GIS coverage of the wastewater collection system was available for a community, then the coverage of the piping was used to determine the service area. The percentage of the sewer system (calculated by length of pipe) in each subbasin was used to distribute the collected wastewater between the subareas.

- **Utility Contact:** If GIS coverage of the wastewater collection system was not available, a representative of the utility for the municipality was contacted. If possible, a description of the collection system (provided either through hard-copy maps or conversations with the representative) was used to establish the wastewater service area. Maps provided by municipalities or developed through conversations with municipal authorities were used in conjunction with MassGIS land use data to determine service areas. The percentage of each service area

Table 5-1
Summary of Existing Wastewater Service Information

Municipality	Wastewater Disposal Status	Source of Sewer Service Area Information	Sewer Discharge Receiving Basin	Title 5 Discharge Receiving Basin
ASHBURNHAM	TITLE 5 & SEWER	GIS COVERAGE	MILLERS	NASHUA/ MERRIMACK/ MILLERS
ASHBY	TITLE 5 ONLY	-	-	NASHUA/ MERRIMACK
AYER	TITLE 5 & SEWER	GIS COVERAGE	NASHUA	NASHUA
BOLTON	TITLE 5 ONLY	-	-	NASHUA/ CONCORD
BOYLSTON	TITLE 5 ONLY	-	-	NASHUA/ BLACKSTONE
CLINTON	TITLE 5 & SEWER	GIS COVERAGE	NASHUA	NASHUA
DEVENS	TITLE 5 & SEWER	GIS COVERAGE	NASHUA	NASHUA
DUNSTABLE	TITLE 5 ONLY	-	-	NASHUA/ MERRIMACK
FITCHBURG	TITLE 5 & SEWER	GIS COVERAGE	NASHUA RIVER NORTH BRANCH	NASHUA
GARDNER	TITLE 5 & SEWER	GIS COVERAGE	MILLERS	NASHUA/ MILLERS
GROTON/WEST G.	TITLE 5 & SEWER	UTILITY CONTACT	NASHUA	NASHUA/ MERRIMACK
HARVARD	TITLE 5 ONLY	-	-	NASHUA
HOLDEN	TITLE 5 & SEWER IN PROGRESS	GIS COVERAGE	BLACKSTONE	NASHUA/ BLACKSTONE
LANCASTER	TITLE 5 & SEWER	MASS GIS LANDUSE	NASHUA	NASHUA
LEOMINSTER	TITLE 5 & SEWER	MASS GIS LANDUSE	NASHUA	NASHUA
LUNENBURG	TITLE 5 & SEWER PROPOSED	UTILITY CONTACT	NASHUA	NASHUA
PAXTON	TITLE 5 ONLY	-	-	NASHUA/ CHICOPEE/ BLACKSTONE
PEPPERELL	TITLE 5 & SEWER	UTILITY CONTACT	NASHUA RIVER	NASHUA
PRINCETON	TITLE 5 ONLY	-	-	NASHUA/ CHICOPEE
RUTLAND	TITLE 5 & SEWER	GIS COVERAGE	BLACKSTONE	CHICOPEE/ NASHUA
SHIRLEY	TITLE 5 & SEWER PROPOSED	UTILITY CONTACT	NASHUA	NASHUA
STERLING	TITLE 5 ONLY	-	-	NASHUA
TOWNSEND	TITLE 5 ONLY	-	-	NASHUA
WEST BOYLSTON	TITLE 5 & SEWER	MASS GIS LANDUSE	BLACKSTONE	NASHUA/ BLACKSTONE
WEST GROTON	TITLE 5 ONLY	-	-	NASHUA
WESTMINSTER	TITLE 5 & SEWER	UTILITY CONTACT	NASHUA	NASHUA/ CHICOPEE/ MILLERS
WORCESTER	SEWER	MASS GIS LANDUSE	BLACKSTONE	-

falling in a particular subarea was used to distribute the amount collected from a community.

- **MassGIS Land Use Data:** If wastewater collection system data were not available through either of the first two means, then MassGIS landuse data were used to approximate service areas. Using MassGIS data, sewer service was assumed to be provided to all developed landuses: Industrial, Commercial, Residential-Multi Family, Residential-Small Lots, and Residential-Medium Lots. The approximate sewered areas were verified using census block data. Census block data provides information on sewered areas. After approximating the service areas using MassGIS data, the method of distributing the amount of wastewater collected among the subareas was the same as when maps were provided by the municipalities.

Exhibit B presents the wastewater service areas obtained using the three methods described above. Table 5-1 summarized the source of service area data for each community. The wastewater systems of non-public dischargers are typically small compared with both municipal collection areas and with the scale of interest of this study, all non-public discharges were collected and discharged to the same subbasin from which they were withdrawn. These discharges are identified as points in Exhibit B.

An improved method for allocating wastewater flow to each subarea would use the number of sewer service connections and / or inch-diameter miles of sewer pipe in a subarea. Though a better method than those discussed above, the information needed to support this method is not available for all communities. However, it is recommended that for future, more detailed subarea analysis, this improved method be considered to distribute wastewater flows to each subarea.

5.4 Planned Service Areas

Four communities—Holden, Lunenburg, Shirley, and West Boylston—were found to have well developed plans for expanding their sewer service area in the future. GIS coverage of the planned development at Holden was available, so that coverage was used to allocate wastewater collection between subareas in future scenarios. Lunenburg, Shirley, and West Boylston did not have GIS coverages available, but hard copy maps and discussions with system managers yielded estimated service areas for these communities in the future. These service areas were likewise used to allocate wastewater collection between the subareas in these municipalities.

The factor of growth of the sewer systems in these communities, based on the relative growth in the service areas, was used as an estimate of future growth in wastewater flows for these communities.

5.5 Existing Wastewater Discharges

Existing (2000) wastewater discharges were calculated based on the average of the 1997-1998 Permit Compliance System (PCS) data for treatment plants that collect wastewater from the Nashua River Watershed. Annual and monthly wastewater flow data were available for all treatment plants in the study. The existing (2000) wastewater flow collected in each community with a collection system is presented in Table 5-2. The table also indicates the wastewater treatment plant to which each community discharges.

To calculate the discharge from each community, as opposed to the discharge from each treatment plant, discharges from the treatment plant were allocated based on the relative service areas of the communities. For example, the Pepperell Wastewater Treatment Plant receives wastewater from both Pepperell and Groton. Because the service area of Pepperell was calculated to be 1.5 times as large as Groton's service area, 60% of the discharge was assumed to be generated in Pepperell, and 40% of the discharge was assumed to be generated in Groton. Of the total annual average flow of 0.48 MGD, 0.29 MGD was assumed to originate in Pepperell, and 0.19 MGD was assumed to originate in Groton.

Three communities in the Wachusett watershed, Holden, Rutland, and West Boylston, discharge or plan to discharge to Worcester's wastewater treatment plant (Upper Blackstone Plant). The estimated present (2000) and future (2020) wastewater flows for these three communities are from the recently completed facilities plan for the Upper Blackstone WWTP. Note that the vast majority of the large wastewater volume from Worcester are both collected and discharged outside of the Nashua River Watershed.

5.6 Future Wastewater Discharges

In general, future wastewater needs were determined by two factors: (1) the growth of the population and water demands and (2) planned sewer system expansions.

- For systems with no expansion of the sewer system currently planned, the wastewater discharge from each plant was assumed to increase by the same proportion as the water demand in the contributing municipalities. This factor was calculated in Section 3, and creates an increase or in some cases a decrease in discharge. For example, Groton was predicted to have a growth factor of 1.81 from 2000 to 2020. Because Groton accounts for 40% of the discharge from the Pepperell Wastewater Treatment Plant, the amount of the wastewater discharged by Groton is 0.48 MGD (the average plant discharge) x 0.40 x 1.72, or 0.33 MGD.

- For systems where future sewer expansion is nearly certain (Lunenburg in particular), wastewater flows were increased by a ratio equal to the increase in service area.

Table 5-2
Existing and Future Wastewater Flow

Municipality	Wastewater Disposal Status	WWTP Facilities	WWTP Subarea/Basin	Fraction of WWTP Facility Flow	2000 Average Annual Collection (MGD)	2020 Average Annual Collection (MGD)
Ashburnham	Sewer & Title 5	Gardner WWTP	Out of Basin	0.148	0.49	0.49
Ashby	Title 5 only	N/A	N/A	0.00	N/A	N/A
Ayer	Sewer & Title 5	Ayer WWTP	Bower Brook	1.00	1.40	2.02
Bolton	Title 5 only	N/A	N/A	0.00	N/A	N/A
Boylston	Title 5 only	N/A	N/A	0.00	N/A	N/A
Clinton	Sewer & Title 5	Clinton WWTP	Nashua River Main Stem 4	0.56	1.51	1.63
Devens	Sewer & Title 5	Devens WWTP	Nashua River Main Stem 2	0.65	0.22	0.37
Dunstable	Title 5 only	N/A	N/A	0.00	N/A	N/A
Fitchburg1	Sewered & Title 5	Fitchburg East WWTP	North Nashua River 2	0.85	6.79	6.71
Fitchburg2	Sewered & Title 5	Fitchburg West WWTP	North Nashua River 3	0.61	2.67	2.64
Gardner	Sewer & Title 5	Gardner WWTP	Out of Basin	0.85	2.81	2.81
Groton	Sewer & Title 5	Pepperell WWTP	Nissitissit River	0.40	0.19	0.33
Harvard	Title 5 only	N/A	N/A	0.00	N/A	N/A
Holden	Title 5 Sewer in Progress	Upper Blackstone WWTP	Blackstone Basin	0.08	0.90	1.60
Lancaster	Sewer & Title 5	Clinton WWTP	Nashua River Main Stem 4	0.44	1.19	1.46
Leominster	Sewer & Title 5	Leominster WWTP	North Nashua River 2	1.00	5.98	7.66
Lunenburg	Title 5 Sewer Proposed	Fitchburg East WWTP	North Nashua River 2	0.15	1.24	4.13
Paxton	Title 5 only	N/A	N/A	0.00	N/A	N/A
Pepperell	Sewer & Title 5	Pepperell WWTP	Nashua River Main Stem 2	0.60	0.29	0.46
Princeton	Title 5 only	N/A	N/A	0.00	N/A	N/A
Rutland	Sewer & Title 5	Upper Blackstone WWTP	Blackstone Basin	0.03	0.46	0.57
Shirley	Title 5 Sewer Proposed	Devens WWTP	N/A	0.35	0.12	0.12
Sterling	Title 5 only	N/A	N/A	0.00	N/A	N/A
Townsend	Title 5 only	N/A	N/A	0.00	N/A	N/A
West Boylston	Sewer & Title 5	Upper Blackstone WWTP	Blackstone Basin	0.00	0.00	0.78
Westminster	Sewer & Title 5	Fitchburg West WWTP	North Nashua River 3	0.39	1.71	2.63
Worcester	Sewer	Upper Blackstone WWTP	Blackstone Basin	0.89	35.16	35.16

The future (2020) wastewater discharge for each community with a wastewater collection system is presented in Table 5-2.

Section 6
Subarea Inflow/Outflow Analysis

6.1 General

This section presents the results of an inflow / outflow analysis for the Nashua River Watershed and its subareas. A water balance was calculated for average present conditions (2000) and for predicted future conditions in 2020. In both the present and future conditions, water balances were calculated for the average annual, average August, and average winter conditions.

Section 6.2 presents the subareas used in this analysis, and the methodology used in the analysis is described in Section 6.3. Sections 6.4 and 6.5 discuss the results of the inflow / outflow analysis for the present and future conditions, respectively.

6.2 Subareas

As part of this study, the Nashua River Watershed was subdivided into 27 separate subareas, which were used to calculate the water balance for the watershed at a smaller scale. This process was performed to determine areas of the watershed that may be at risk, as well as areas that may have the potential for additional withdrawal. These 27 subareas have been grouped into five separate subwatersheds within the Nashua River Watershed: the Wachusett Watershed, the North Nashua River Watershed, the Squannacook River Watershed, the Nissitissit River Watershed, and the separate subareas contributing to the Main Stem of the Nashua River. The boundaries and names of the subareas are presented in Figure 6-1.

6.3 Inflow/Outflow Methodology

The general approach used in this inflow / outflow analysis was to tally the sources and uses of water in each subarea within the Nashua River Watershed. Water supply records were used to determine the amount of water withdrawn from each subarea for each scenario. The service area of each public distribution system was then used to distribute the water from each water supply to the appropriate subareas. The wastewater discharge from each wastewater treatment plant (WWTP) was then allocated as an inflow to the subarea in which the WWTP was located. Wastewater records were used in conjunction with sewer service areas to determine the amount of wastewater collected from each subarea. The net of these inflows and outflows was then calculated to arrive at the water balance for each subarea in the Nashua River Watershed.

Water flows for communities without public water supply or public wastewater systems were not included in the inflow / outflow analysis. Water flow from individual on-site wells and on-site septic systems were assumed to return the water to the same subarea as the source. Additionally, evaporative losses from artificially impounded reaches are not included in the analysis.

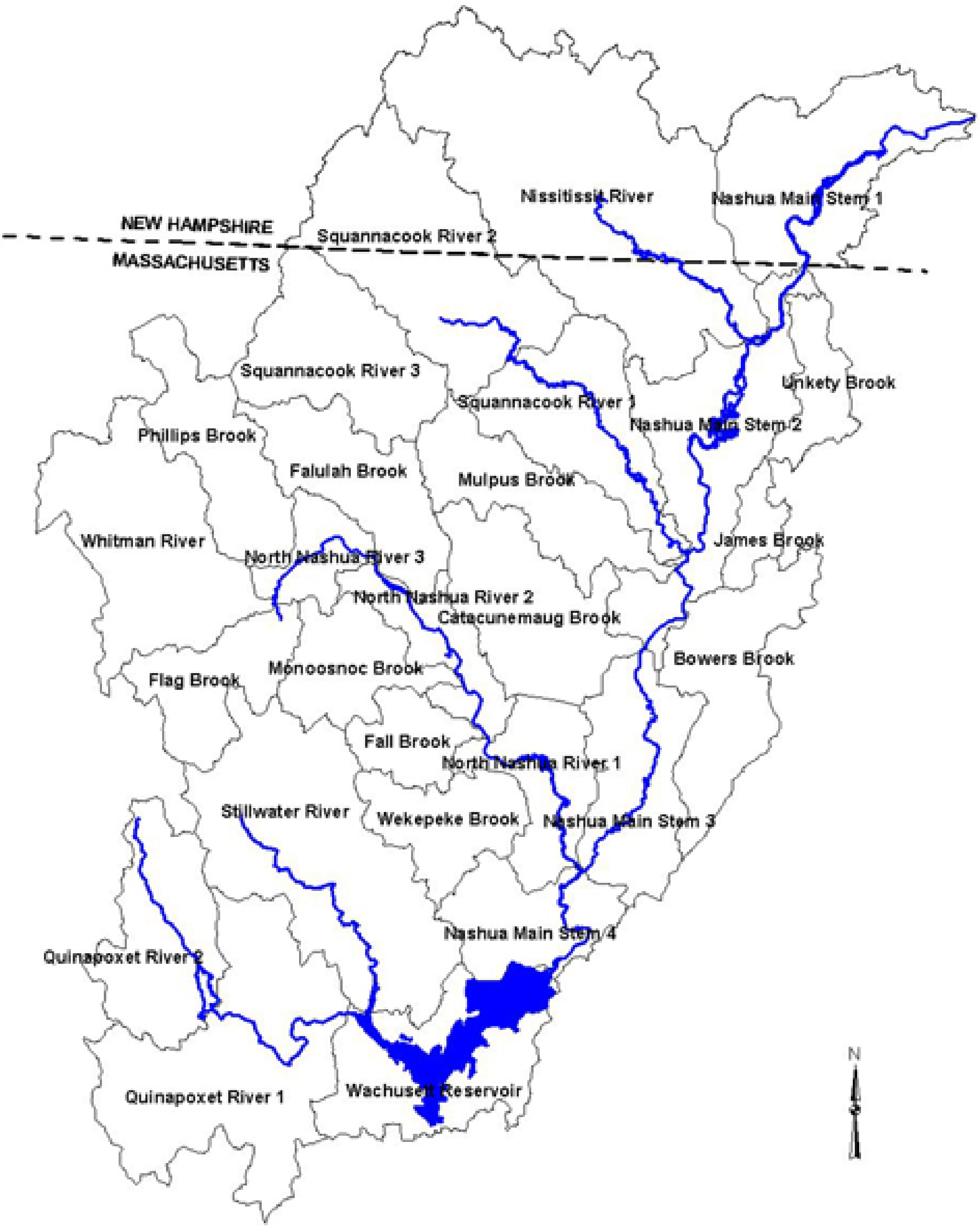


Figure 6-1
Nashua River Watershed Subareas

CDM

A limitation of the method is the subarea scale. The analysis is limited to assessing the inflow/outflow of the subarea as a unit. Within the subarea, individual streams or areas may have large outflows while other streams or areas within the subarea have large inflows. It is recommended that when individual subareas are examined, smaller subarea sizes (subareas of the subareas) be used to allow for a more detailed assessment.

Following is a more detailed description of the basin inflow/outflow analysis.

SCENARIOS:

Three scenarios were used to evaluate water balances for each year. The Average Daily Demand (ADD) provided average annual conditions. The average August demand provided typical high demand, low flow conditions in the summer, and the average winter demand provided typical low demand, high flow conditions in the winter. Following is a more detailed description of these scenarios.

Average Daily Demand (ADD)

This is a standard term, indicating that it is a typical or average day in a given year. In this report, the ADD was calculated for municipalities in Section 3, based on ASR data from 1994-1998. ADD is the total annual withdrawal divided by 365 days. For non-public water supplies, the ADD was calculated directly by taking the average withdrawal from the ASR data from 1994-1998.

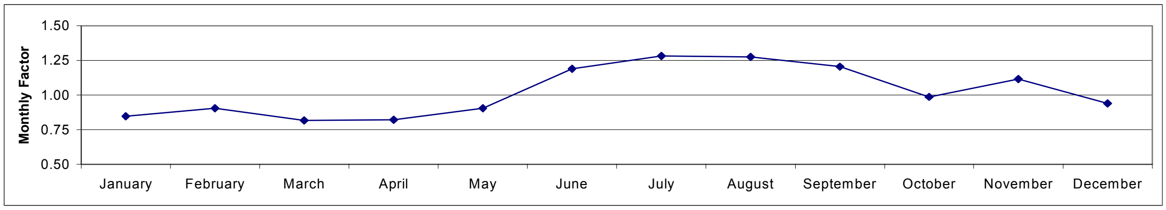
August Average Day Demand

This is not a standard term. In this report August Average Demand was calculated from ADD using the monthly pattern for each municipality. For most municipalities, average monthly data were available from the ASR data. In these cases, a monthly factor was calculated by dividing the average monthly demand (August) by the average annual demand for each municipality. This factor was multiplied by the ADD to determine the Average August Demand.

For some municipalities and most non-public supplies, average monthly data were not available from the ASR data. In these cases, an aggregate monthly factor was used based on the monthly data from other communities. The average monthly factors for all municipalities in the watershed with monthly data were calculated by dividing the sum of the monthly demands by the sum of the annual demands. The average monthly factors for all municipalities in the watershed, calculated from the 1994-1998 ASR data, are presented in Figure 6-2.

Figure 6-2
Monthly Flow Factors Applied to Sources with No Monthly Data

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Factor	0.85	0.90	0.82	0.82	0.90	1.19	1.28	1.28	1.20	0.99	1.12	0.94



Note that many non-public industrial supplies did not have monthly data. In these cases, no attempt was made to apply a monthly factor to obtain the August Average Day Demand. Instead, the ADD was used because either (1) the demand may be fairly level throughout the year or (2) not enough data was available to predict temporal variations in industrial demand.

Winter Average Day Demand

Like the August Average Day Demand, this is not a standard term. This value was used as a typical “base” demand, typically lower than the ADD, where residential flows dominate because lawn watering, car washing, and other outdoor uses of water are minimal during winter. This value was applied (1) to estimate the amount of water lost to evaporation (see discussion in Step 2 for more information) and (2) as a scenario to illustrate possible periods of lower demand and higher stream flow. To calculate the Winter Average Day Demand, the same procedures were followed as for the August Average Day Demand, except that the average of December, January, and February was used instead of August.

STEP 1: WATER SUPPLY SOURCES

GIS was used to determine the subarea containing each water supply source. The sources within each subarea were then totaled to obtain a total water withdrawal for each subarea. This step included the following procedures:

- Determine the subarea for each source (public and non-public)

  This was accomplished by performing a GIS intersection of the withdrawal locations point theme with the subareas theme, thereby obtaining the location (subarea name) of each supply source. If the sources were not within the Nashua River Watershed, they were not included in this portion of the analysis, but they were included as a portion of the water distribution analysis (STEP 2). A matrix describing which communities withdrew water from which subarea is presented in Table 6-1.

Table 6-1
Matrix of Community Withdrawals from Subareas

	Bowers Brook	Catacunemaug Brook	Fall Brook	Falulah Brook	Flag Brook	James Brook	Monoosnoc Brook	Mulpus Brook	Nashua River Main Stem 1	Nashua River Main Stem 2	Nashua River Main Stem 3	Nashua River Main Stem 4	Nissitissit River	North Nashua River 1	North Nashua River 2	North Nashua River 3	Phillips Brook	Quinapoxet River 1	Quinapoxet River 2	Squannacook River 1	Squannacook River 2	Squannacook River 3	Stillwater River	Unkety Brook	Wachusett Reservoir	Wekepeke Brook	Whitman River
Ashburnham																	✓										
Ashby																											
Ayer	✓																										
Bolton																											
Boylston																											
Clinton																									✓		
Devens	✓										✓																
Fitchburg				✓	✓											✓					✓						
Harvard	✓																										
Holden																		✓	✓								
Lancaster												✓															
Leominster			✓				✓																			✓	
Lunenburg		✓						✓																			
Paxton																		✓									
Pepperell										✓			✓														
Princeton																											
Rutland																			✓								
Shirley		✓						✓		✓										✓							
Sterling																							✓				
Townsend																				✓	✓						
West Boylston																									✓		
West Groton																				✓							
Westminster					✓																						
Worcester																			✓								

NOTE: a "✓" means that the community has at least one withdrawal in a particular subareas
Ashby, Bolton, and Princeton do not have public water supply systems.

- Determine appropriate withdrawal for each water supply source

  The ADD for each municipality was calculated in Section 3, based on ASR data from 1994-1998. The ADD for each municipality was then used as a base demand, and the withdrawal for each water supply source was calculated based on the percent of the municipal demand that it represented, on average, from 1994-1998. For example, Falulah Reservoir, in the Falulah Brook Subarea, supplied approximately 19% of the demand for Fitchburg, based on ASR data from 1994-1998. Since the ADD for Fitchburg in the year 2000 was calculated to be 5.95 MGD in Section 3, the ADD withdrawal for Falulah Reservoir subarea would be 0.19 x 5.95, or 1.13 MGD. The analysis was then similarly expanded to calculate withdrawals for each of the scenarios described above (August Average, Winter Average for 2000 and 2020).

- Add up all the withdrawals in each subarea to determine total withdrawal from each subarea.

  After determining the appropriate subarea and withdrawal for each supply source in the watershed, the total withdrawals for each subarea were calculated by summing the individual withdrawals in each subarea. The resulting total withdrawals in each subarea for each the scenarios are presented in Table 6-2.

STEP 2: WATER DISTRIBUTION

Using the distribution service areas for each municipality, water supplies were distributed to each subarea using the appropriate percentage of each municipal demand for each subarea. This involved the following procedures:

- Determine water distribution service areas

  Water distribution service areas were presented in Section 3.

- Determine percent of each community's water distribution area in each subarea

  Using the distribution service areas developed in Section 3, an intersection was performed using GIS to determine the percent of each community's water distribution system within each subarea. Depending on the source of the distribution data, the percent may have been calculated based on the length of water pipe in each subarea or by the area of land serviced in each subarea. Section 3 describes the sources of data for each municipality in detail. Table 6-3 presents a matrix showing communities that distributed water to each subarea.

- Distribute water to each subarea, based on municipal demand and percent of the water distribution system in each subarea

  Total demand for each municipality was distributed to each subarea based on the percent of the water distribution system in each subarea. For example, the

Table 6-2
Water Withdrawn from Each Subarea for Water Supply

	2000 Average Daily Withdrawal (MGD)	2000 Average August Withdrawal (MGD)	2000 Average Winter Withdrawal (MGD)	2020 Average Daily Withdrawal (MGD)	2020 Average August Withdrawal (MGD)	2020 Average Winter Withdrawal (MGD)
Wachusett Watershed						
Quinapoxet River 2	0.78	1.00	0.56	1.12	1.37	0.86
Worcester Withdrawal[1]	9.21	16.82	7.74	9.57	17.47	8.04
Quinapoxet River 1	1.46	1.67	1.34	1.59	1.80	1.48
Stillwater River	0.51	0.61	0.44	0.80	0.95	0.70
Wachusett Reservoir	2.82	3.10	2.70	3.02	3.31	2.89
MWRA Withdrawal from Wachusett[2]	148.00	148.00	148.00	148.00	148.00	148.00
Wachusett Without Worcester & MWRA	5.57	6.36	5.05	6.53	7.43	5.93
Wachusett Total	**162.79**	**171.18**	**160.79**	**164.11**	**172.90**	**161.97**
North Nashua River Watershed						
Phillips Brook	0.00	0.00	0.00	0.00	0.00	0.00
Whitman River	1.22	1.64	0.93	1.22	1.64	0.93
Flag Brook	4.65	5.24	4.53	4.74	5.36	4.61
North Nashua River 3	1.71	1.96	1.64	1.71	1.95	1.63
Monoosnoc Brook	3.10	3.15	3.02	3.97	4.03	3.87
Falulah Brook	1.27	1.39	1.13	1.25	1.38	1.12
North Nashua River 2	0.00	0.00	0.00	0.00	0.00	0.00
Fall Brook	0.65	0.76	0.60	0.83	0.97	0.77
Wekepeke Brook	0.31	0.98	0.04	0.40	1.25	0.05
North Nashua River 1	0.00	0.00	0.00	0.00	0.00	0.00
North Nashua River Total	**12.91**	**15.12**	**11.90**	**14.12**	**16.58**	**12.99**
Squannacook River Watershed						
Squannacook River 3	0.00	0.00	0.00	0.00	0.00	0.00
Squannacook River 2	0.45	0.54	0.39	0.70	0.84	0.60
Squannacook River 1	2.78	2.55	2.66	2.88	2.70	2.72
Mulpus Brook	0.45	0.67	0.39	0.49	0.75	0.42
Squannacook River Total	**3.69**	**3.77**	**3.44**	**4.07**	**4.29**	**3.74**
Nissitissit River Watershed						
Nissitissit River	0.59	0.67	0.58	0.96	1.07	0.94
Nissitissit River Total	**0.59**	**0.67**	**0.58**	**0.96**	**1.07**	**0.94**
Nashua River Main Stem						
Nashua River Main Stem 4	0.56	0.66	0.49	0.68	0.80	0.60
Nashua River Main Stem 3	0.07	0.04	0.11	0.07	0.04	0.11
Bowers Brook	0.78	0.95	0.70	0.98	1.14	0.88
Catacunemaug Brook	0.46	0.45	0.38	0.59	0.58	0.50
James Brook	0.00	0.00	0.00	0.00	0.00	0.00
Nashua River Main Stem 2	1.65	1.81	1.42	2.02	2.32	1.73
Unkety Brook	0.00	0.00	0.00	0.00	0.00	0.00
Nashua River Main Stem 1	0.00	0.00	0.00	0.00	0.00	0.00
Nashua River Main Stem Total	**3.52**	**3.91**	**3.10**	**4.35**	**4.88**	**3.82**
NASHUA W/OUT WORCESTER & MWRA	**26.28**	**29.82**	**24.08**	**30.03**	**34.26**	**27.41**
NASHUA TOTAL	**183.50**	**194.64**	**179.82**	**187.60**	**199.73**	**183.45**

[1] Worcester draws from a reservoir at the downsteam end of the Quinapoxet 2 Subarea
[2] MWRA draws from Washusett Reservoir, at the downstream end of the Wachusett Watershed

Table 6-3
Matrix of Community Water Distribution to Subareas

	Bowers Brook	Catacunemaug Brook	Fall Brook	Falulah Brook	Flag Brook	James Brook	Monoosnoc Brook	Mulpus Brook	Nashua River Main Stem 1	Nashua River Main Stem 2	Nashua River Main Stem 3	Nashua River Main Stem 4	Nissitissit River	North Nashua River 1	North Nashua River 2	North Nashua River 3	Phillips Brook	Quinapoxet River 1	Quinapoxet River 2	Squannacook River 1	Squannacook River 2	Squannacook River 3	Stillwater River	Unkety Brook	Wachusett Reservoir	Wekepeke Brook	Whitman River
Ashburnham																	✓										✓
Ashby																											
Ayer	✓									✓																	
Bolton																											
Boylston																									✓		
Clinton												✓													✓		
Devens	✓	✓								✓	✓																
Dunstable									✓	✓														✓			
Fitchburg				✓	✓		✓								✓	✓	✓					✓					✓
Gardner																											✓
Groton						✓				✓										✓				✓			
Harvard	✓										✓																
Holden																		✓	✓						✓		
Lancaster											✓	✓		✓												✓	
Leominster		✓	✓	✓	✓		✓							✓	✓								✓			✓	
Lunenburg		✓		✓				✓							✓					✓							
Paxton																		✓									
Pepperell									✓	✓			✓							✓				✓			
Princeton																											
Rutland																			✓								
Shirley		✓						✓		✓	✓																
Sterling												✓											✓		✓	✓	
Townsend								✓					✓							✓	✓	✓					
West Boylston																		✓					✓		✓		
Westminster					✓																						✓
Worcester																		✓							✓		

NOTE: a " ✓ " means that the community distributes water to a particular subareas

Fitchburg water distribution system is located in eight subareas. 26% of the system is located in Falulah Brook subarea, so 26% of the Fitchburg water supply was distributed to Falulah Brook subarea. Since the Average Daily Demand for Fitchburg was determined to be 5.95 MGD, 1.55 MGD was distributed to the Falulah Brook subarea from Fitchburg (other municipalities also distributed water to Falulah Brook subarea as well).

Because non-public supplies (i.e. registered and permitted non-community) were small in scale compared with the subareas used in this study, all demand for non-public supplies was distributed to the same subarea from which it was withdrawn.

- Special treatment of August distribution—To account for outside water use, 50% of the difference between August Average and Winter Average demands was assumed to be lost from the water balance due to irrigation, car washing, etc. for public water supplies. The 50% loss of outside water use is an approximate value. The actual value can vary widely depending on the efficiency of the system and the individual user. Also, because individuals with on-site wells and septic systems were considered small and not included in the analysis, their water lost (plant uptake and evaporation) from outside water use was not considered in the analysis.

  In most cases, water use increases in the summertime as the result of increased lawn watering and irrigation. Because approximately half of the water used in typical residential irrigation evaporates, an allowance was made to prevent the overestimation of the amount of water returned to each subarea. This allowance was determined by calculating the winter average day demand—by averaging December, January, and February—to be used as an average "base demand" representing no outdoor use of water. Half of all flow above that "base demand" in August was assumed to evaporate before being returned to the subarea for the water balance. In cases where the August demand was less than the winter average day demand (i.e. assumed evaporation would be negative), no evaporation was assumed, and the distribution was not adjusted.

- Sum amount distributed to each subarea

  After determining the proper distribution of water for each community, the amount distributed to each subarea was summed among the communities to determine a total amount of water distributed to each subarea. The amount of water distributed to each subarea in each scenario is presented in Table 6-4.

STEP 3: WASTEWATER DISCHARGE

Wastewater discharge represents the outflow from each wastewater treatment plant into the appropriate stream or river. These discharges were added to the subarea in

Table 6-4
Water Distributed to Each Subarea by Water Supply

	2000 Average Daily Distribution (MGD)	2000 Average August Distribution (MGD)	2000 Average Winter Distribution (MGD)	2020 Average Daily Distribution (MGD)	2020 Average August Distribution (MGD)	2020 Average Winter Distribution (MGD)
Wachusett Watershed						
Quinapoxet River 2	0.22	0.21	0.20	0.38	0.37	0.34
Worcester Withdrawal[1]	0.00	0.00	0.00	0.00	0.00	0.00
Quinapoxet River 1	1.56	1.81	1.29	1.70	1.96	1.42
Stillwater River	0.50	0.52	0.45	0.70	0.73	0.62
Wachusett Reservoir	0.98	1.06	0.87	1.15	1.25	0.99
MWRA Withdrawal from Wachusett[2]	0.00	0.00	0.00	0.00	0.00	0.00
Wachusett Without Worcester & MWRA	3.26	3.60	2.80	3.93	4.30	3.37
Wachusett Total	**3.26**	**3.60**	**2.80**	**3.93**	**4.30**	**3.37**
North Nashua River Watershed						
Phillips Brook	0.23	0.23	0.21	0.23	0.23	0.20
Whitman River	1.64	2.15	1.33	1.72	2.23	1.39
Flag Brook	1.27	1.34	1.25	1.32	1.40	1.30
North Nashua River 3	3.58	3.52	3.31	3.55	3.50	3.28
Monoosnoc Brook	1.11	1.15	1.00	1.34	1.38	1.20
Falulah Brook	1.85	1.85	1.61	1.90	1.90	1.65
North Nashua River 2	2.69	2.76	2.41	3.14	3.22	2.81
Fall Brook	1.16	1.21	1.05	1.49	1.56	1.34
Wekepeke Brook	0.14	0.15	0.12	0.21	0.22	0.18
North Nashua River 1	0.35	0.36	0.31	0.43	0.44	0.38
North Nashua River Total	**14.02**	**14.71**	**12.59**	**15.32**	**16.07**	**13.75**
Squannacook River Watershed						
Squannacook River 3	0.06	0.06	0.05	0.06	0.06	0.05
Squannacook River 2	0.26	0.27	0.20	0.40	0.42	0.32
Squannacook River 1	0.43	0.45	0.35	0.68	0.72	0.55
Mulpus Brook	0.19	0.20	0.16	0.24	0.25	0.21
Squannacook River Total	**0.93**	**0.98**	**0.77**	**1.39**	**1.46**	**1.13**
Nissitissit River Watershed						
Nissitissit River	0.39	0.42	0.35	0.62	0.68	0.56
Nissitissit River Total	**0.39**	**0.42**	**0.35**	**0.62**	**0.68**	**0.56**
Nashua River Main Stem						
Nashua River Main Stem 4	2.17	2.23	2.07	2.42	2.48	2.30
Nashua River Main Stem 3	0.13	0.14	0.13	0.17	0.17	0.16
Bowers Brook	1.30	1.40	1.23	1.70	1.79	1.59
Catacunemaug Brook	0.79	0.83	0.70	1.00	1.05	0.89
James Brook	0.05	0.06	0.04	0.09	0.10	0.08
Nashua River Main Stem 2	1.25	1.32	1.13	1.85	1.95	1.67
Unkety Brook	0.08	0.09	0.07	0.13	0.14	0.11
Nashua River Main Stem 1	0.01	0.01	0.01	0.01	0.01	0.01
Nashua River Main Stem Total	**5.79**	**6.06**	**5.38**	**7.37**	**7.70**	**6.81**
NASHUA W/OUT WORCESTER & MWRA	**24.39**	**25.78**	**21.88**	**28.62**	**30.21**	**25.62**
NASHUA TOTAL	**24.39**	**25.78**	**21.88**	**28.62**	**30.21**	**25.62**

which the treatment plant was located. The following procedures were included in this step:

- Determine subarea for each wastewater discharge

  General wastewater discharge information was presented in Section 2 and 5. In order to determine the specific subarea of discharge, the wastewater discharge locations were intersected with the subareas in GIS. A matrix of the WWTPs discharge to each subarea is presented in Table 6-5.

- Sum the amount wastewater discharge to each subarea

  The individual wastewater discharges to each subarea were summed to obtain a total wastewater discharge to each subarea. These wastewater discharges are summarized for each scenario in Table 6-6.

STEP 4: WASTEWATER COLLECTION

Disposal of wastewater in the Nashua River Watershed has two forms: on-site disposal of wastewater through a Title 5 septic system, or discharge to a sewer system that conveys the wastewater flows to a treatment plant. On-site disposal of wastewater discharges the wastewater into the subarea to where the water is distributed. Wastewater discharged to a sewer system may remove the wastewater flow to another subarea, depending on where the wastewater treatment plant is located. The following discussion presents the method used to account for wastewater collection.

Wastewater collection from each subarea was calculated similarly to water distribution to each subarea, except that the total wastewater discharges and sewered areas were used instead of water demands and water service areas, respectively. The following procedures were involved in this step:

- Determine the sewer service areas

  Sewer service areas were presented in Section 5.

- Determine the fraction of wastewater treatment plant discharge belonging to each community (for facilities that serve multiple communities).

  In cases where a wastewater treatment facility served multiple communities, the fraction of the facility discharge from each community was determined by comparing the relative sizes of the sewer systems for each community, either based on total length of sewer or based on total area served.

  In cases where multiple facilities served a single (or multiple) communities, the percent served by each facility was determined by delineating the actual sewer service area for each facility to the greatest extent possible: by examining sewer

Table 6-5
Matrix of Community Wastewater Discharge to Subareas

	Bowers Brook	Catacunemaug Brook	Fall Brook	Falulah Brook	Flag Brook	James Brook	Monoosnoc Brook	Mulpus Brook	Nashua River Main Stem 1	Nashua River Main Stem 2	Nashua River Main Stem 3	Nashua River Main Stem 4	Nissitissit River	North Nashua River 1	North Nashua River 2	North Nashua River 3	Phillips Brook	Quinapoxet River 1	Quinapoxet River 2	Squannacook River 1	Squannacook River 2	Squannacook River 3	Stillwater River	Unkety Brook	Wachusett Reservoir	Wekepeke Brook	Whitman River
Ashburnham																											
Ashby																											
Ayer	✓																										
Bolton																											
Boylston																											
Clinton												✓															
Devens										✓																	
Dunstable																											
Fitchburg															✓	✓											
Gardner																											
Groton													✓														
Harvard																											
Holden																											
Lancaster												✓															
Leominster															✓												
Lunenburg															✓												
Paxton																											
Pepperell										✓																	
Princeton																											
Rutland																											
Shirley																											
Sterling																											
Townsend																											
West Boylston																											
Westminster																✓											
Worcester																											

NOTE: a " ✓ " means that the community discharges wastewater to a particular subarea
This includes communities that discharge to another community's wastewater treatment plant
Towns for which wastewater discharges are not indicated either have no centralized wastewater collection system or discharge water out of the basin.

Table 6-6
Amount of Wastewater Discharged to Each Subarea

	2000 Average Daily Discharged (MGD)	2000 Average August Discharged (MGD)	2000 Average Winter Discharged (MGD)	2020 Average Daily Discharged (MGD)	2020 Average August Discharged (MGD)	2020 Average Winter Discharged (MGD)
Wachusett Watershed						
Quinapoxet River 2	-	-	-	-	-	-
Worcester Withdrawal[1]	-	-	-	-	-	-
Quinapoxet River 1	-	-	-	-	-	-
Stillwater River	-	-	-	-	-	-
Wachusett Reservoir	-	-	-	-	-	-
MWRA Withdrawal from Wachusett[2]	-	-	-	-	-	-
Wachusett Without Worcester & MWRA	-	-	-	-	-	-
Wachusett Total	**-**	**-**	**-**	**-**	**-**	**-**
North Nashua River Watershed						
Phillips Brook	-	-	-	-	-	-
Whitman River	-	-	-	-	-	-
Flag Brook	-	-	-	-	-	-
North Nashua River 3	4.66	4.95	4.79	5.56	5.90	5.71
Monoosnoc Brook	-	-	-	-	-	-
Falulah Brook	-	-	-	-	-	-
North Nashua River 2	14.00	10.25	15.57	15.72	11.59	17.38
Fall Brook	-	-	-	-	-	-
Wekepeke Brook	-	-	-	-	-	-
North Nashua River 1	-	-	-	-	-	-
North Nashua River Total	**18.67**	**15.20**	**20.36**	**21.28**	**17.48**	**23.09**
Squannacook River Watershed						
Squannacook River 3	-	-	-	-	-	-
Squannacook River 2	-	-	-	-	-	-
Squannacook River 1	2.53	2.53	2.53	2.53	2.53	2.53
Mulpus Brook	-	-	-	-	-	-
Squannacook River Total	**2.53**	**2.53**	**2.53**	**2.53**	**2.53**	**2.53**
Nissitissit River Watershed						
Nissitissit River	0.19	0.18	0.18	0.33	0.31	0.32
Nissitissit River Total	**0.19**	**0.18**	**0.18**	**0.33**	**0.31**	**0.32**
Nashua River Main Stem						
Nashua River Main Stem 4	2.77	2.08	2.89	3.15	2.37	3.29
Nashua River Main Stem 3	-	-	-	-	-	-
Bowers Brook	1.40	1.36	1.36	2.02	1.96	1.96
Catacunemaug Brook	0.01	0.01	0.01	0.01	0.01	0.01
James Brook	-	-	-	-	-	-
Nashua River Main Stem 2	2.00	1.90	2.05	2.33	2.21	2.37
Unkety Brook	-	-	-	-	-	-
Nashua River Main Stem 1	-	-	-	-	-	-
Nashua River Main Stem Total	**6.18**	**5.34**	**6.31**	**7.52**	**6.55**	**7.63**
NASHUA W/OUT WORCESTER & MWRA	**27.57**	**23.25**	**29.38**	**31.65**	**26.88**	**33.57**
NASHUA TOTAL	**27.57**	**23.25**	**29.38**	**31.65**	**26.88**	**33.57**

maps, discussions with utility managers, and topographic maps. The resulting sewer service areas were then analyzed separately.

- Determine wastewater discharge for each community and each wastewater treatment plant

  The discharge from each community was determined by taking the fraction of the wastewater facility belonging to that community times the average wastewater discharge provided in 1997-1998 PCS data. For example, the Fitchburg West Wastewater Treatment Plant serves Fitchburg and Westminster. Based on the relative size of the service areas, Fitchburg was estimated to contribute 61% of the wastewater to the Fitchburg West WWTP. The average discharge from the WWTP in 1997-1998 was 4.38 MGD, so the contribution from Fitchburg was 2.67 MGD. Note that Fitchburg also discharges via the Fitchburg East WWTP, and the calculation of the service area and discharge volume related to that wastewater plant had no relation to the Fitchburg West WWTP.

- Determine the percent of each sewer service area within each subarea

  Using the sewer service areas developed in Section 5, an intersection was performed using GIS to determine the percent of each sewer system within each subarea. Depending on the source of the data, the percent may have been calculated based on the length of sewer pipe in each subarea or by the area of land serviced in each subarea. Section 5 describes the sources of data for each municipality in detail. A matrix of the communities that collected wastewater from each subarea is presented in Table 6-7.

- For each municipality, apply each subarea's percent of the service area to the total amount collected from the municipality at each treatment plant; in order to calculate the amount of wastewater collected from each subarea.

  Total wastewater collection from each municipality was allocated to each subarea based on the percent of the sewer system in each subarea. For example, the Fitchburg portion of the Fitchburg West Wastewater Treatment Plant (note that there are two treatment plants for Fitchburg, each with a separate service area) sewer system is located in five subareas. 25% of the system is located in Falulah Brook subarea, so 25% of the Fitchburg West WWTP wastewater discharge was assumed to be collected from Falulah Brook. Since the wastewater discharge for Fitchburg's portion of the West Fitchburg WWTP was determined to be 2.67 MGD, 0.25 x 2.67, or 0.67 MGD of wastewater was collected from the Falulah Brook subarea from the Fitchburg West WWTP sewer system (other municipalities collected wastewater from Falulah Brook subarea as well).

  Because non-public supplies were small in scale compared with the subareas used in this study, all wastewater for non-public supplies was distributed to the same subarea from which it was withdrawn.

Table 6-7
Matrix of Community Wastewater Collection Systems in each Subarea

	Bowers Brook	Catacunemaug Brook	Fall Brook	Falulah Brook	Flag Brook	James Brook	Monoosnoc Brook	Mulpus Brook	Nashua River Main Stem 1	Nashua River Main Stem 2	Nashua River Main Stem 3	Nashua River Main Stem 4	Nissitissit River	North Nashua River 1	North Nashua River 2	North Nashua River 3	Phillips Brook	Quinapoxet River 1	Quinapoxet River 2	Squannacook River 1	Squannacook River 2	Squannacook River 3	Stillwater River	Unkety Brook	Wachusett Reservoir	Wekepeke Brook	Whitman River
Ashburnham																	✓										✓
Ashby																											
Ayer	✓									✓																	
Bolton																											
Boylston																											
Clinton												✓													✓		
Devens	✓	✓								✓	✓																
Dunstable																											
Fitchburg				✓			✓								✓	✓	✓										
Gardner																											✓
Groton						✓				✓																	
Harvard																											
Holden																		✓							✓		
Lancaster		✓									✓	✓		✓												✓	
Leominster		✓	✓	✓			✓							✓	✓												
Lunenburg		✓		✓																							
Paxton																											
Pepperell										✓			✓											✓			
Princeton																											
Rutland																			✓								
Shirley		✓						✓		✓	✓																
Sterling																											
Townsend																											
West Boylston																											
Westminster					✓																						✓
Worcester																		✓							✓		

NOTE: a "✓" means that the community collects wastewater from a particular subarea
Not all communities have wastewater collection systems in the basin.

- Sum amount collected from each subarea

  After determining the amount of wastewater collected from each municipality in each subarea, the total wastewater collected from each subarea was calculated. The total amount of wastewater collected from each subarea is presented in Table 6-8.

STEP 5: CALCULATE INFLOW/OUTFLOW BALANCE

After the first four steps are complete, the core pieces of the water balance are known. The remaining task is to calculate the water balance for each subarea. This is done by taking inflows minus outflows, or water distribution plus wastewater discharge (inflows) minus water withdrawal and wastewater collection (outflows). This calculation was performed for each subarea in each scenario. The results of these calculations are presented in Table 6-9 for 2000 Annual, Table 6-10 for August 2000, and Table 6-11 for Winter 2000. These results are also presented graphically in Figures 6-3 through 6-5 for the annual, August, and winter inflow/outflow balances, respectively.

The inflow/outflow for one subarea is informative by example. As discussed in earlier steps, Falulah Brook subarea has water withdrawals, water distribution systems, and wastewater collection systems. The inflow/outflow or water balance shows the net effect of all the inflows and outflows. For example, on Table 6-9, the 2000 Annual summary, Falulah Brook subarea has the following inflows and outflows:

Water supply withdrawal of:	1.266 mgd	(outflow)
Water distribution of:	1.719 mgd	(inflow)
Wastewater collection of:	1.755mgd	(outflow)
Wastewater discharge of:	0.0 mgd	(inflow)

For a net loss of 1.302 mgd (-1.266 + 1.719 - 1.755 = 1.302 mgd)

This method is applied to each subarea and then the total net change for all subareas are totaled to determine the net change in the Nashua River watershed.

6.4 Existing Inflow/Outflow

The existing (year 2000) inflow/outflow analysis will be discussed for the annual and August scenarios.

6.4.1 Average Annual 2000

The 2000 annual inflow/outflow is presented in Table 6-9 and Figure 6-3.

Table 6-8
Amount of Wastewater Collected from Each Subarea from Sewer Systems

	2000 Average Daily Collection (MGD)	2000 Average August Collection (MGD)	2000 Average Winter Collection (MGD)	2020 Average Daily Collection (MGD)	2020 Average August Collection (MGD)	2020 Average Winter Collection (MGD)
Wachusett Watershed						
Quinapoxet River 2	0.26	0.21	0.26	0.32	0.38	0.48
Worcester Withdrawal[1]	0.00	0.00	0.00	0.00	0.00	0.00
Quinapoxet River 1	0.66	0.53	0.66	1.15	1.05	1.31
Stillwater River	0.00	0.00	0.00	0.13	0.10	0.13
Wachusett Reservoir	0.18	0.14	0.18	1.00	0.80	1.01
MWRA Withdrawal from Wachusett[2]	0.00	0.00	0.00	0.00	0.00	0.00
Wachusett Without Worcester & MWRA	1.10	0.88	1.10	2.60	2.33	2.93
Wachusett Total	**1.10**	**0.88**	**1.10**	**2.60**	**2.33**	**2.93**
North Nashua River Watershed						
Phillips Brook	1.12	0.78	1.27	1.11	0.77	1.26
Whitman River	1.39	1.34	1.42	1.95	1.93	2.00
Flag Brook	0.68	0.72	0.70	1.05	1.11	1.08
North Nashua River 3	7.85	5.87	8.94	7.76	5.80	8.83
Monoosnoc Brook	1.43	1.14	1.52	1.75	1.38	1.85
Falulah Brook	0.90	0.89	0.95	1.00	0.95	1.06
North Nashua River 2	3.25	2.76	3.41	3.93	3.29	4.13
Fall Brook	1.45	1.13	1.53	1.86	1.44	1.95
Wekepeke Brook	0.01	0.01	0.01	0.02	0.01	0.02
North Nashua River 1	0.61	0.46	0.64	0.75	0.57	0.79
North Nashua River Total	**18.70**	**15.09**	**20.39**	**21.18**	**17.26**	**22.97**
Squannacook River Watershed						
Squannacook River 3	0.00	0.00	0.00	0.00	0.00	0.00
Squannacook River 2	0.00	0.00	0.00	0.00	0.00	0.00
Squannacook River 1	0.00	0.00	0.00	0.00	0.00	0.00
Mulpus Brook	0.12	0.09	0.12	0.12	0.09	0.13
Squannacook River Total	**0.12**	**0.09**	**0.12**	**0.12**	**0.09**	**0.13**
Nissitissit River Watershed						
Nissitissit River	0.05	0.04	0.04	0.07	0.07	0.07
Nissitissit River Total	**0.05**	**0.04**	**0.04**	**0.07**	**0.07**	**0.07**
Nashua River Main Stem						
Nashua River Main Stem 4	2.09	1.57	2.18	2.34	1.76	2.44
Nashua River Main Stem 3	0.15	0.11	0.16	0.20	0.15	0.21
Bowers Brook	0.97	0.92	0.97	1.06	1.00	1.06
Catacunemaug Brook	0.63	0.49	0.67	0.88	0.68	0.93
James Brook	0.06	0.06	0.06	0.11	0.10	0.11
Nashua River Main Stem 2	1.05	0.98	1.03	1.30	1.23	1.28
Unkety Brook	0.03	0.03	0.03	0.05	0.05	0.05
Nashua River Main Stem 1	0.00	0.00	0.00	0.00	0.00	0.00
Nashua River Main Stem Total	**4.99**	**4.17**	**5.11**	**5.94**	**4.98**	**6.08**
NASHUA W/OUT WORCESTER & MWRA	**24.96**	**20.27**	**26.77**	**29.91**	**24.73**	**32.17**
NASHUA TOTAL	**24.96**	**20.27**	**26.77**	**29.91**	**24.73**	**32.17**

Table 6-9
2000 Annual Inflow/Outflow Analysis

	Amount Withdrawn (MGD)	Amount Distributed (MGD)	Amount Collected (MGD)	Amount Discharged (MGD)	TOTAL BALANCE (MGD)
Wachusett Watershed					
Quinapoxet River 2	0.780	0.215	0.260	-	(0.825)
Worcester Withdrawal[1]	9.215	-	-	-	(9.215)
Quinapoxet River 1	1.460	1.558	0.659	-	(0.561)
Stillwater River	0.511	0.504	-	-	(0.008)
Wachusett Reservoir	2.820	0.979	0.178	-	(2.019)
MWRA Withdrawal from Wachusett[2]	148.000	-	-	-	(148.000)
Wachusett Without Worcester & MWRA	5.571	3.255	1.096	-	(3.413)
Wachusett Total	**162.786**	**3.255**	**1.096**	**-**	**(160.627)**
North Nashua River Watershed					
Phillips Brook	0.001	0.233	1.124	-	(0.893)
Whitman River	1.220	1.644	1.394	-	(0.970)
Flag Brook	4.647	1.265	0.678	-	(4.060)
North Nashua River 3	1.712	3.578	7.849	4.664	(1.318)
Monoosnoc Brook	3.099	1.113	1.432	-	(3.418)
Falulah Brook	1.266	1.852	0.905	-	(0.319)
North Nashua River 2	0.001	2.694	3.254	14.001	13.441
Fall Brook	0.647	1.159	1.449	-	(0.937)
Wekepeke Brook	0.314	0.142	0.013	-	(0.185)
North Nashua River 1	-	0.345	0.608	-	(0.262)
North Nashua River Total	**12.906**	**14.024**	**18.705**	**18.665**	**1.078**
Squannacook River Watershed					
Squannacook River 3	-	0.060	-	-	0.060
Squannacook River 2	0.453	0.259	-	-	(0.194)
Squannacook River 1	2.784	0.430	-	2.533	0.179
Mulpus Brook	0.454	0.186	0.116	-	(0.384)
Squannacook River Total	**3.691**	**0.935**	**0.116**	**2.533**	**(0.340)**
Nissitissit River Watershed					
Nissitissit River	0.594	0.388	0.046	0.191	(0.061)
Nissitissit River Total	**0.594**	**0.388**	**0.046**	**0.191**	**(0.061)**
Nashua River Main Stem					
Nashua River Main Stem 4	0.562	2.174	2.087	2.770	2.296
Nashua River Main Stem 3	0.074	0.134	0.153	-	(0.094)
Bowers Brook	0.778	1.303	0.975	1.398	0.948
Catacunemaug Brook	0.455	0.787	0.634	0.010	(0.292)
James Brook	-	0.054	0.064	-	(0.011)
Nashua River Main Stem 2	1.651	1.247	1.046	2.002	0.551
Unkety Brook	-	0.078	0.033	-	0.046
Nashua River Main Stem 1	-	0.008	-	-	0.008
Nashua River Main Stem Total	**3.521**	**5.785**	**4.992**	**6.180**	**3.452**
NASHUA W/OUT WORCESTER & MWRA	**26.28**	**24.39**	**24.96**	**27.57**	**0.72**
NASHUA TOTAL	**183.50**	**24.39**	**24.96**	**27.57**	**(156.50)**

NOTE: TOTAL BALANCE = -AMOUNT WITHDRAWN + AMOUNT DISTRIBUTED - AMOUNT COLLECTED + AMOUNT DISCHARGED

Table 6-10
August 2000 Inflow/Outflow Analysis

	Amount Withdrawn (MGD)	Amount Distributed (MGD)	Amount Collected (MGD)	Amount Discharged (MGD)	TOTAL BALANCE (MGD)
Wachusett Watershed					
Quinapoxet River 2	0.995	0.210	0.208	-	(0.993)
Worcester Withdrawal[1]	16.817	-	-	-	(16.817)
Quinapoxet River 1	1.665	1.813	0.527	-	(0.379)
Stillwater River	0.606	0.523	-	-	(0.083)
Wachusett Reservoir	3.098	1.058	0.142	-	(2.181)
MWRA Withdrawal from Wachusett[2]	148.000	-	-	-	(148.000)
Wachusett Without Worcester & MWRA	6.365	3.605	0.877	-	(3.637)
Wachusett Total	**171.182**	**3.605**	**0.877**	**-**	**(168.454)**
North Nashua River Watershed					
Phillips Brook	0.001	0.230	0.779	-	(0.551)
Whitman River	1.643	2.148	1.339	-	(0.833)
Flag Brook	5.241	1.339	0.722	-	(4.624)
North Nashua River 3	1.955	3.524	5.871	4.946	0.645
Monoosnoc Brook	3.149	1.147	1.138	-	(3.140)
Falulah Brook	1.393	1.848	0.886	-	(0.431)
North Nashua River 2	0.001	2.757	2.759	10.250	10.247
Fall Brook	0.758	1.215	1.127	-	(0.670)
Wekepeke Brook	0.975	0.147	0.010	-	(0.838)
North Nashua River 1	-	0.356	0.459	-	(0.102)
North Nashua River Total	**15.116**	**14.711**	**15.089**	**15.196**	**(0.298)**
Squannacook River Watershed					
Squannacook River 3	-	0.059	-	-	0.059
Squannacook River 2	0.541	0.270	-	-	(0.271)
Squannacook River 1	2.550	0.454	-	2.533	0.438
Mulpus Brook	0.675	0.196	0.090	-	(0.568)
Squannacook River Total	**3.766**	**0.980**	**0.090**	**2.533**	**(0.342)**
Nissitissit River Watershed					
Nissitissit River	0.668	0.423	0.043	0.180	(0.108)
Nissitissit River Total	**0.668**	**0.423**	**0.043**	**0.180**	**(0.108)**
Nashua River Main Stem					
Nashua River Main Stem 4	0.657	2.228	1.571	2.079	2.080
Nashua River Main Stem 3	0.043	0.140	0.114	-	(0.017)
Bowers Brook	0.946	1.397	0.917	1.355	0.889
Catacunemaug Brook	0.448	0.831	0.492	0.010	(0.099)
James Brook	-	0.058	0.061	-	(0.003)
Nashua River Main Stem 2	1.814	1.316	0.984	1.898	0.417
Unkety Brook	-	0.086	0.031	-	0.055
Nashua River Main Stem 1	-	0.009	-	-	0.009
Nashua River Main Stem Total	**3.907**	**6.065**	**4.169**	**5.343**	**3.331**
NASHUA W/OUT WORCESTER & MWRA	**29.82**	**25.78**	**20.27**	**23.25**	**(1.05)**
NASHUA TOTAL	**194.64**	**25.78**	**20.27**	**23.25**	**(165.87)**

NOTE: TOTAL BALANCE = -AMOUNT WITHDRAWN + AMOUNT DISTRIBUTED - AMOUNT COLLECTED + AMOUNT DISCHARGED

Table 6-11
Winter 2000 Inflow/Outflow Analysis

	Amount Withdrawn (MGD)	Amount Distributed (MGD)	Amount Collected (MGD)	Amount Discharged (MGD)	TOTAL BALANCE (MGD)
Wachusett Watershed					
Quinapoxet River 2	0.564	0.197	0.260	-	(0.627)
Worcester Withdrawal[1]	7.740	-	-	-	(7.740)
Quinapoxet River 1	1.344	1.292	0.659	-	(0.711)
Stillwater River	0.445	0.448	-	-	0.003
Wachusett Reservoir	2.701	0.865	0.178	-	(2.014)
MWRA Withdrawal from Wachusett[2]	148.000	-	-	-	(148.000)
Wachusett Without Worcester & MWRA	5.054	2.801	1.097	-	(3.350)
Wachusett Total	**160.794**	**2.801**	**1.097**	**-**	**(159.090)**
North Nashua River Watershed					
Phillips Brook	0.001	0.205	1.271	-	(1.067)
Whitman River	0.933	1.329	1.424	-	(1.027)
Flag Brook	4.531	1.249	0.698	-	(3.980)
North Nashua River 3	1.636	3.308	8.935	4.791	(2.472)
Monoosnoc Brook	3.023	0.997	1.522	-	(3.547)
Falulah Brook	1.133	1.614	0.950	-	(0.469)
North Nashua River 2	0.000	2.408	3.409	15.570	14.569
Fall Brook	0.601	1.045	1.526	-	(1.082)
Wekepeke Brook	0.043	0.124	0.014	-	0.067
North Nashua River 1	-	0.308	0.636	-	(0.328)
North Nashua River Total	**11.901**	**12.588**	**20.385**	**20.361**	**0.663**
Squannacook River Watershed					
Squannacook River 3	-	0.052	-	-	0.052
Squannacook River 2	0.389	0.205	-	-	(0.185)
Squannacook River 1	2.661	0.349	-	2.533	0.221
Mulpus Brook	0.391	0.159	0.125	-	(0.357)
Squannacook River Total	**3.442**	**0.765**	**0.125**	**2.533**	**(0.268)**
Nissitissit River Watershed					
Nissitissit River	0.585	0.349	0.044	0.184	(0.096)
Nissitissit River Total	**0.585**	**0.349**	**0.044**	**0.184**	**(0.096)**
Nashua River Main Stem					
Nashua River Main Stem 4	0.491	2.068	2.177	2.891	2.291
Nashua River Main Stem 3	0.107	0.132	0.165	-	(0.140)
Bowers Brook	0.695	1.228	0.970	1.355	0.918
Catacunemaug Brook	0.384	0.700	0.675	0.010	(0.349)
James Brook	-	0.044	0.062	-	(0.018)
Nashua River Main Stem 2	1.424	1.132	1.035	2.050	0.724
Unkety Brook	-	0.069	0.031	-	0.037
Nashua River Main Stem 1	-	0.007	-	-	0.007
Nashua River Main Stem Total	**3.101**	**5.380**	**5.115**	**6.306**	**3.471**
NASHUA W/OUT WORCESTER & MWRA	**24.08**	**21.88**	**26.77**	**29.38**	**0.42**
NASHUA TOTAL	**179.82**	**21.88**	**26.77**	**29.38**	**(155.32)**

NOTE: TOTAL BALANCE = -AMOUNT WITHDRAWN + AMOUNT DISTRIBUTED - AMOUNT COLLECTED + AMOUNT DISCHARGED

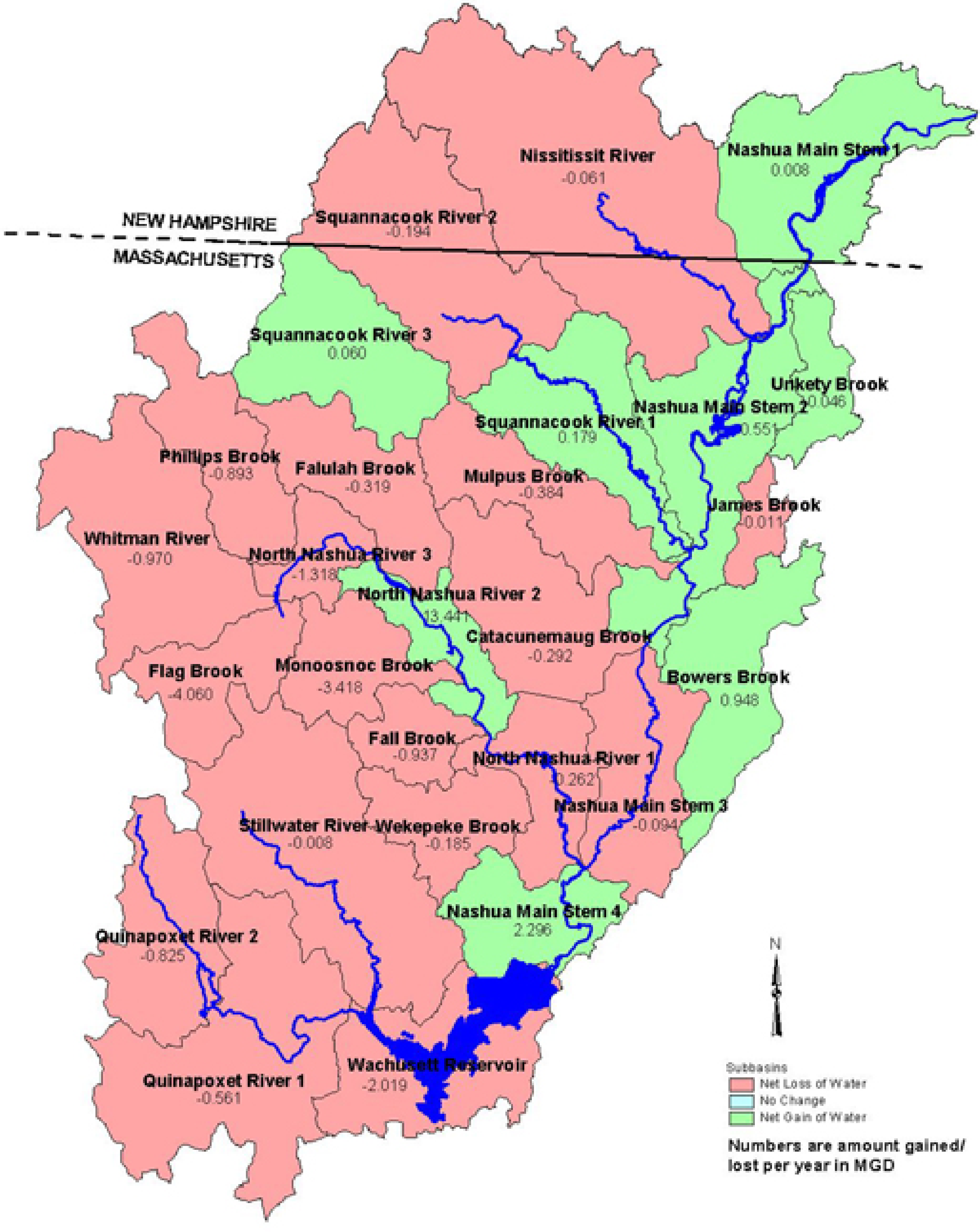


Figure 6-3
Average 2000 Nashua River Watershed Water Balance

CDM

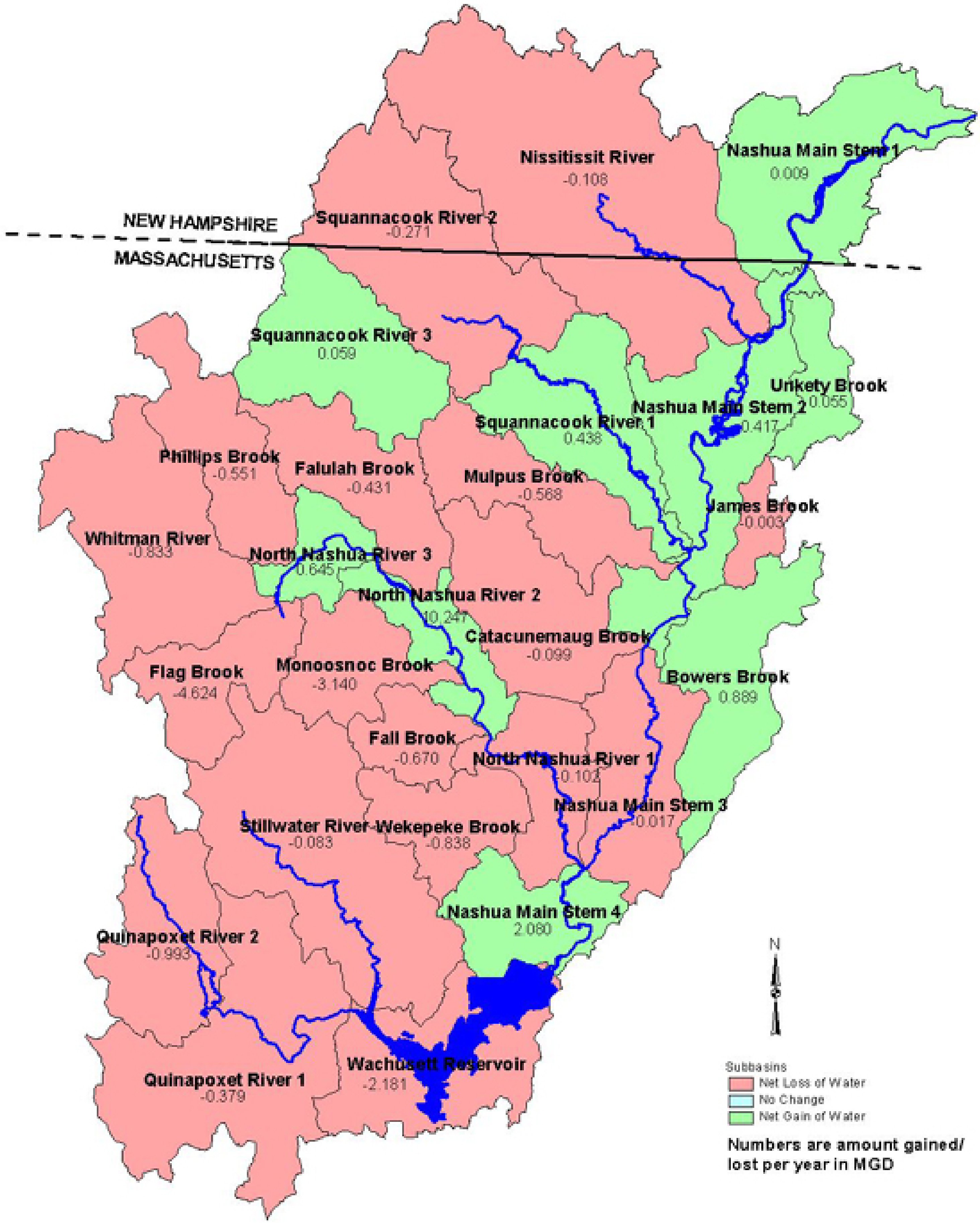


Figure 6-4
August 2000 Nashua River Watershed Water Balance

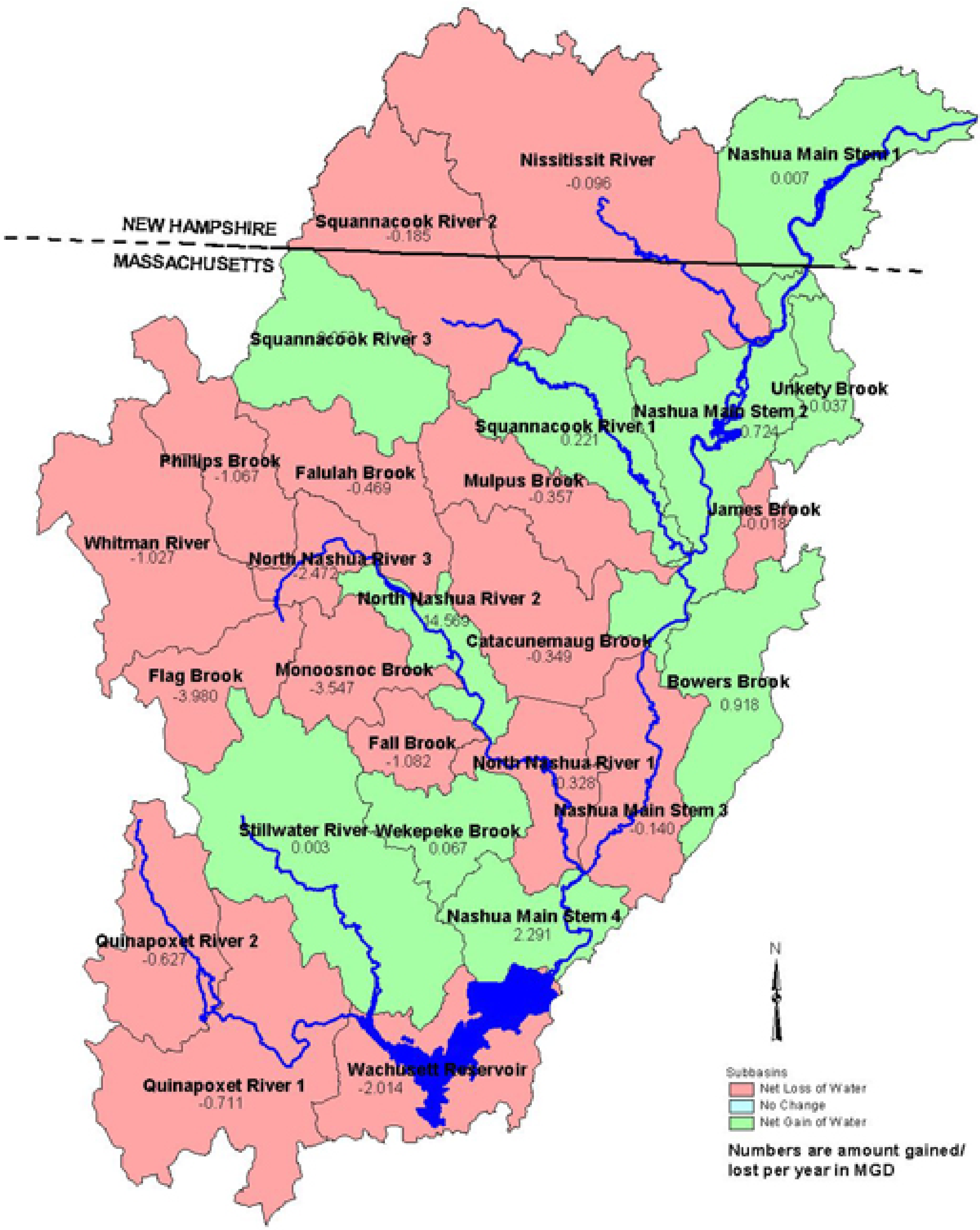


Figure 6-5
Winter 2000 Nashua River Watershed Water Balance

CDM

Watershed-wide Findings

- For the 2000 annual inflow / outflow, there is a net gain of 0.7 mgd for the Nashua River watershed or a net loss of 156.5 mgd when MWRA's and Worcester's water withdrawals are included.

- Excluding Worcester's and MWRA's large water withdrawals, there is a net loss of water in the watershed due to water withdrawal and distribution. The difference in water withdrawn (26.3 mgd) to water distributed (24.4 mgd), is a loss of 1.9 mgd from the watershed.

- The amount of wastewater discharged, 27.6 mgd, is greater than the amount of wastewater collected, 25.0 mgd, for a gain of 2.6 mgd. Comparing the water withdrawn / distributed and the waster discharged / collected, there is a net gain of 0.7 mgd to the watershed.

- The findings for individual subareas in the watershed are more telling. Of the 27 subareas in the watershed, only eight have a net gain of flow, and 19 subareas have net losses of flow. Of the eight subareas that gain flow, five of these subareas gain flow from having a wastewater treatment plant discharge in the subarea.

Wachusett Subwatershed

The inflow / outflow balance at the subwatershed level is more revealing. The Wachusett subwatershed is dominated by large withdrawals by the City of Worcester and MWRA for water supply that removes the water from the Nashua River Watershed.

- For the 2000 annual inflow / outflow, the Wachusett subwatershed has a net loss of 3.4 mgd or a net loss of 160.6 mgd when MWRA's and Worcester's water withdrawals are included.

- The Wachusett subwatershed has net loss of water in each the four subareas, even without the large water withdrawals of MWRA and Worcester.

- The net loss of water to the subwatershed is primarily from local water supply withdrawal by Rutland, Clinton, Holden, Paxton, and West Boylston and the sewering and conveyance of wastewater out of the watershed, primarily by Holden and Rutland. These losses create the annual loss of 3.4 mgd. Of course, large withdrawals for water supply by Worcester and MWRA create the large net loss of 160.6 mgd of water.

North Nashua River Subwatershed

The North Nashua subwatershed flow balance has large withdrawals in the headwaters for water supply and large wastewater discharge in the middle and downstream portions of the subwatershed. Several of the watershed's large cities are in the subwatershed, including Fitchburg and Leominster.

- Three large wastewater discharges in the subwatershed contribute to an overall net gain of water of 1.1 mgd.

- Nine out of the ten subareas have a net loss of water. Only the subarea North Nashua River 2 (which includes the Fitchburg East and Leominster Wastewater Treatment Plants) has a net gain of water. Even the subarea North Nashua River 3—where the Fitchburg West Wastewater Treatment Plant discharges—has a net loss of water.

- This overall net gain of water from the subwatershed is primarily from having some water supply sources in other subwatersheds that are distributed in North Nashua River subwatershed. This finding can be seen in Table 6-9 at the North Nashua River total line: 12.9 mgd of water withdrawn and 14.0 mgd of flow distributed, or a net gain of 1.1 mgd.

- Several North Nashua subareas have large net loss of water. Flag Brook and Monoosnoc Brook subareas have a net loss of 4.1 mgd and 3.4 mgd, respectively. Large withdrawals for water supply are located in each of these subareas. Flag Brook has water supplies for Fitchburg, Custom Papers Group, Inc, and Westminster. Monoosnoc Brook has Leominster withdrawals.

Squannacook River Subwatershed

The Squannacook River Subwatershed has much less development, and hence water withdrawal, water distribution, wastewater collection, and wastewater discharge in the subwatershed. Major communities in the subwatershed include Townsend, Lunenburg, and Shirley.

- The Squannacook River subwatershed has a small loss, 0.3 mgd, of water.

- Two out of four subareas in the subwatershed lose water. Mulpus Brook has a loss of water, from Lunenburg and Shirley water supplies, which remove the water from the subwatershed. Squannacook River 2 loses water from Townsend water withdrawals.

- The loss of water from the subwatershed is primarily from having water distribution systems that extend across subwatershed boundaries. Neglecting the withdrawal of Hollingsworth & Vose Co. (which is discharged within the subarea), 1.2 mgd of water is withdrawn, but only 1.0 mgd is distributed within the subwatershed.

Nissitissit River Subwatershed

The Nissitissit River subwatershed is partially in New Hampshire, but the river flows southeast and joins the Nashua River in Massachusetts. Pepperell is the community with water supplies in the subwatershed.

- The subwatershed has a net loss of 0.06 mgd.

Nashua River Main Stem Subwatershed

The Nashua River main stem subwatershed is from the Wachusett Dam to the Massachusetts state line. Numerous communities, including Clinton, Lancaster, Harvard, Shirley, Ayer, Groton, Pepperell, and Dunstable are in the subwatershed.

- The subwatershed has a net gain of water, 3.5 mgd. The net gain is from having a greater amount of water distributed (5.8 mgd) than water withdrawn (3.5 mgd). Hence, the water supplies for several of the communities, Clinton, Pepperell, Ayer, Leominster, and Shirley, are outside the subwatershed.

- The Nashua River Main Stem subwatershed also has greater wastewater discharged (6.2 mgd) than wastewater collected (5.0 mgd).

- Three out of the eight subareas in the subwatershed have a loss of water. Three of the five subareas that gain water have a wastewater treatment plant discharge in the subarea.

6.4.2 August 2000

The August 2000 inflow / outflow is presented in Table 6-10 and Figure 6-4.

Watershed-Wide Findings

- For this scenario, there is a net loss of 1.1 mgd for the Nashua River watershed or a net loss of 165.9 mgd if MWRA's and Worcester's withdrawals are included.

- Excluding Worcester's and MWRA's large water withdrawals, there is a net loss of 4.0 mgd from the watershed resulting from the difference between water withdrawn (29.8 mgd) and water distributed (25.8 mgd).

- The amount of wastewater discharged, 23.3 mgd, is greater than the amount of wastewater collected, 20.3 mgd, for a gain of 3.0 mgd. Hence, there is a net loss of 1.0 mgd from the watershed.

- These results are in contrast to the annual findings, where there was a net gain of water (0.7 mgd) to the watershed. This change is primarily from outdoor water use, which is a water loss from the watershed through evaporation.

- Water withdrawn in August (29.8 mgd) increased by 3.5 mgd over the annual amount withdrawn (26.3 mgd), primarily to meet the greater summer water demand.

- Of the 27 subareas in the watershed, nine have a net gain of water, and 18 subareas have a loss of water.

Wachusett Subwatershed

The Wachusett subwatershed is dominated by large withdrawals by the City of Worcester and MWRA for water supply that removes the water from the Nashua River Watershed.

- For the August 2000 inflow / outflow, the Wachusett subwatershed has a net loss of 3.6 mgd or a net loss of 168.5 mgd when MWRA's and Worcester's water withdrawals are included.

- The Wachusett subwatershed has net loss of water in each the four subareas, even without the large water withdrawals of MWRA and Worcester. This is the same as the annual findings. The overall net loss of water is slightly greater for the August condition (3.6 mgd) than the average annual condition (3.4 mgd).

- The net loss of water to the subwatershed is primarily from local water supply withdrawal out of the subwatershed and the sewering and conveyance of wastewater out of the watershed. These create the August loss of 3.6 mgd. Of course, large withdrawals for water supply by Worcester and MWRA create the large net loss of 168.5 mgd of water.

North Nashua River Subwatershed

- Despite having three large wastewater discharges in the subwatershed, there is overall net loss of water of 0.3 mgd.

- Eight out of the ten subareas have a net loss of water. Only two subareas have a net gain of water: North Nashua River 3, with Fitchburg West Wastewater Treatment Plant's discharge, and North Nashua River 2, with the Fitchburg East and Leominster Wastewater Treatment Plants' discharges.

- Several North Nashua subareas have large net losses of water. Flag Brook and Monoosnoc Brook subareas have net losses of 4.6 mgd and 3.1 mgd, respectively. Large withdrawals for water supply are located in each of these subareas.

Squannacook River Subwatershed

- The Squannacook River subwatershed has a small loss, 0.3 mgd, of water.

- Two out of four subareas in the subwatershed lose water, including Mulpus Brook and Squannacook River 2.

Nissitissit River Subwatershed

- The subwatershed has a net loss of 0.1 mgd.

Nashua River Main Stem Subwatershed

- The subwatershed has a net gain of water, 3.3 mgd. The net gain is primarily from having a greater amount of water distributed (6.1 mgd) than water withdrawn (3.9 mgd).

- Three out of the eight subareas in the subwatershed have a loss of water. Three of the five subareas that gain water have wastewater treatment plant discharges in the subarea.

6.5 Projected Future Inflow/Outflow

The results of this analysis show that the combination of increased water demands, the expansion of sewer systems, and increased wastewater treatment will create greater discrepancies in water balance between subareas in the Nashua River Watershed. Tables 6-12, 6-13 and 6-14 present the inflow / outflow water balance for the Annual 2020, August 2020, and Winter 2020 scenarios, respectively. These results are also presented in Figures 6-6, 6-7 and 6-8 for the Annual 2020, August 2020, and Winter 2020 scenarios, respectively. Because additional water will be withdrawn from subareas with water supplies, the loss of water from most subareas is expected to increase. The treated water is largely returned to the river, creating an overall increase in the river flow. However, because the wastewater is generally being discharged directly to the main stem of the streams, wastewater treatment is not expected to significantly help the water balance in any particular subarea.

6.5.1 2020 Annual

- For this scenario, there is a net gain of 0.3 mgd for the Nashua River watershed or a net loss of 157.2 mgd if MWRA's and Worcester's withdrawals are included.

- Excluding Worcester's and MWRA's large water withdrawals, there is a loss of 1.4 mgd from the watershed caused by the difference between water withdrawn (30.0 mgd) and water distributed (28.6 mgd).

- The amount of wastewater discharged, 31.7 mgd, is greater than the amount of wastewater collected, 29.9 mgd, for a gain of 1.8 mgd. Hence, there is a gain of 0.3 mgd from the watershed.

- The predicted amount of water withdrawn in 2020 (30.0 mgd) will increase by 3.8 mgd over the annual amount withdrawn in 2000 (26.2 mgd), primarily to meet the increase in water demand.

- Wastewater collection increases from 25.0 mgd in 2000 to 29.9 mgd in 2020, an increase of 4.9 mgd.

- Of the 27 subareas in the watershed, nine have a net gain of water, and 18 have a net loss of water.

Table 6-12
2020 Annual Inflow/Outflow Analysis

	Amount Withdrawn (MGD)	Amount Distributed (MGD)	Amount Collected (MGD)	Amount Discharged (MGD)	TOTAL BALANCE (MGD)
Wachusett Watershed					
Quinapoxet River 2	1.123	0.376	0.322	-	(1.069)
Worcester Withdrawal[1]	9.573	-	-	-	(9.573)
Quinapoxet River 1	1.594	1.699	1.150	-	(1.044)
Stillwater River	0.802	0.704	0.128	-	(0.226)
Wachusett Reservoir	3.016	1.146	1.000	-	(2.869)
MWRA Withdrawal from Wachusett[2]	148.000	-	-	-	(148.000)
Wachusett Without Worcester & MWRA	6.535	3.926	2.600	-	(5.209)
Wachusett Total	**164.107**	**3.926**	**2.600**	**-**	**(162.781)**
North Nashua River Watershed					
Phillips Brook	0.001	0.230	1.113	-	(0.885)
Whitman River	1.220	1.716	1.952	-	(1.456)
Flag Brook	4.736	1.322	1.046	-	(4.460)
North Nashua River 3	1.708	3.549	7.757	5.559	(0.357)
Monoosnoc Brook	3.969	1.336	1.748	-	(4.380)
Falulah Brook	1.251	1.898	1.002	-	(0.355)
North Nashua River 2	0.001	3.137	3.933	15.718	14.921
Fall Brook	0.828	1.487	1.855	-	(1.196)
Wekepeke Brook	0.402	0.211	0.016	-	(0.207)
North Nashua River 1	-	0.429	0.753	-	(0.324)
North Nashua River Total	**14.116**	**15.315**	**21.176**	**21.276**	**1.300**
Squannacook River Watershed					
Squannacook River 3	-	0.062	-	-	0.062
Squannacook River 2	0.702	0.403	-	-	(0.299)
Squannacook River 1	2.877	0.680	-	2.533	0.336
Mulpus Brook	0.489	0.242	0.119	-	(0.367)
Squannacook River Total	**4.069**	**1.386**	**0.119**	**2.533**	**(0.268)**
Nissitissit River Watershed					
Nissitissit River	0.956	0.624	0.074	0.329	(0.077)
Nissitissit River Total	**0.956**	**0.624**	**0.074**	**0.329**	**(0.077)**
Nashua River Main Stem					
Nashua River Main Stem 4	0.683	2.421	2.338	3.155	2.555
Nashua River Main Stem 3	0.074	0.166	0.199	-	(0.107)
Bowers Brook	0.983	1.701	1.060	2.024	1.681
Catacunemaug Brook	0.591	1.004	0.877	0.010	(0.454)
James Brook	-	0.092	0.111	-	(0.018)
Nashua River Main Stem 2	2.022	1.849	1.302	2.326	0.852
Unkety Brook	-	0.126	0.053	-	0.073
Nashua River Main Stem 1	-	0.013	-	-	0.013
Nashua River Main Stem Total	**4.354**	**7.372**	**5.939**	**7.515**	**4.594**
NASHUA W/OUT WORCESTER & MWRA	**30.03**	**28.62**	**29.91**	**31.65**	**0.34**
NASHUA TOTAL	**187.60**	**28.62**	**29.91**	**31.65**	**(157.23)**

NOTE: TOTAL BALANCE = -AMOUNT WITHDRAWN + AMOUNT DISTRIBUTED - AMOUNT COLLECTED + AMOUNT DISCHARGED

Table 6-13
August 2020 Inflow/Outflow Analysis

	Amount Withdrawn (MGD)	Amount Distributed (MGD)	Amount Collected (MGD)	Amount Discharged (MGD)	TOTAL BALANCE (MGD)
Wachusett Watershed					
Quinapoxet River 2	1.366	0.366	0.383	-	(1.383)
Worcester Withdrawal[1]	17.470	-	-	-	(17.470)
Quinapoxet River 1	1.802	1.957	1.048	-	(0.893)
Stillwater River	0.950	0.730	0.101	-	(0.322)
Wachusett Reservoir	3.312	1.249	0.801	-	(2.864)
MWRA Withdrawal from Wachusett[2]	148.000	-	-	-	(148.000)
Wachusett Without Worcester & MWRA	7.430	4.301	2.333	-	(5.462)
Wachusett Total	**172.900**	**4.301**	**2.333**	**-**	**(170.932)**
North Nashua River Watershed					
Phillips Brook	0.001	0.227	0.772	-	(0.546)
Whitman River	1.643	2.226	1.933	-	(1.349)
Flag Brook	5.360	1.401	1.113	-	(5.072)
North Nashua River 3	1.950	3.496	5.802	5.898	1.642
Monoosnoc Brook	4.033	1.383	1.384	-	(4.034)
Falulah Brook	1.376	1.896	0.952	-	(0.432)
North Nashua River 2	0.001	3.224	3.285	11.585	11.523
Fall Brook	0.971	1.560	1.443	-	(0.853)
Wekepeke Brook	1.249	0.218	0.012	-	(1.043)
North Nashua River 1	-	0.444	0.569	-	(0.125)
North Nashua River Total	**16.584**	**16.075**	**17.264**	**17.483**	**(0.290)**
Squannacook River Watershed					
Squannacook River 3	-	0.062	-	-	0.062
Squannacook River 2	0.841	0.421	-	-	(0.419)
Squannacook River 1	2.699	0.719	-	2.533	0.554
Mulpus Brook	0.748	0.253	0.092	-	(0.587)
Squannacook River Total	**4.288**	**1.455**	**0.092**	**2.533**	**(0.391)**
Nissitissit River Watershed					
Nissitissit River	1.075	0.681	0.070	0.310	(0.154)
Nissitissit River Total	**1.075**	**0.681**	**0.070**	**0.310**	**(0.154)**
Nashua River Main Stem					
Nashua River Main Stem 4	0.798	2.482	1.757	2.365	2.292
Nashua River Main Stem 3	0.043	0.171	0.153	-	(0.024)
Bowers Brook	1.142	1.792	1.002	1.961	1.610
Catacunemaug Brook	0.580	1.054	0.683	0.010	(0.199)
James Brook	-	0.099	0.105	-	(0.005)
Nashua River Main Stem 2	2.317	1.954	1.227	2.213	0.622
Unkety Brook	-	0.137	0.049	-	0.087
Nashua River Main Stem 1	-	0.014	-	-	0.014
Nashua River Main Stem Total	**4.880**	**7.703**	**4.976**	**6.549**	**4.397**
NASHUA W/OUT WORCESTER & MWRA	**34.26**	**30.21**	**24.73**	**26.88**	**(1.90)**
NASHUA TOTAL	**199.73**	**30.21**	**24.73**	**26.88**	**(167.37)**

NOTE: TOTAL BALANCE = -AMOUNT WITHDRAWN + AMOUNT DISTRIBUTED - AMOUNT COLLECTED + AMOUNT DISCHARGED

Table 6-14
Winter 2020 Inflow/Outflow Analysis

	Amount Withdrawn (MGD)	Amount Distributed (MGD)	Amount Collected (MGD)	Amount Discharged (MGD)	TOTAL BALANCE (MGD)
Wachusett Watershed					
Quinapoxet River 2	0.862	0.344	0.478	-	(0.996)
Worcester Withdrawal[1]	8.041	-	-	-	(8.041)
Quinapoxet River 1	1.479	1.417	1.310	-	(1.372)
Stillwater River	0.697	0.623	0.128	-	(0.203)
Wachusett Reservoir	2.889	0.986	1.013	-	(2.916)
MWRA Withdrawal from Wachusett[2]	148.000	-	-	-	(148.000)
Wachusett Without Worcester & MWRA	5.927	3.370	2.930	-	(5.487)
Wachusett Total	**161.968**	**3.370**	**2.930**	**-**	**(161.528)**
North Nashua River Watershed					
Phillips Brook	0.001	0.203	1.259	-	(1.057)
Whitman River	0.933	1.394	1.998	-	(1.536)
Flag Brook	4.608	1.300	1.076	-	(4.384)
North Nashua River 3	1.633	3.283	8.830	5.712	(1.469)
Monoosnoc Brook	3.871	1.199	1.855	-	(4.526)
Falulah Brook	1.119	1.649	1.063	-	(0.533)
North Nashua River 2	0.000	2.808	4.125	17.379	16.062
Fall Brook	0.770	1.342	1.955	-	(1.383)
Wekepeke Brook	0.055	0.184	0.017	-	0.112
North Nashua River 1	-	0.383	0.789	-	(0.406)
North Nashua River Total	**12.989**	**13.745**	**22.967**	**23.091**	**0.880**
Squannacook River Watershed					
Squannacook River 3	-	0.054	-	-	0.054
Squannacook River 2	0.604	0.318	-	-	(0.286)
Squannacook River 1	2.716	0.553	-	2.533	0.370
Mulpus Brook	0.416	0.206	0.127	-	(0.338)
Squannacook River Total	**3.737**	**1.131**	**0.127**	**2.533**	**(0.200)**
Nissitissit River Watershed					
Nissitissit River	0.941	0.561	0.071	0.317	(0.134)
Nissitissit River Total	**0.941**	**0.561**	**0.071**	**0.317**	**(0.134)**
Nashua River Main Stem					
Nashua River Main Stem 4	0.599	2.298	2.439	3.292	2.553
Nashua River Main Stem 3	0.107	0.163	0.212	-	(0.156)
Bowers Brook	0.878	1.593	1.055	1.961	1.621
Catacunemaug Brook	0.504	0.894	0.930	0.010	(0.531)
James Brook	-	0.076	0.107	-	(0.031)
Nashua River Main Stem 2	1.731	1.666	1.282	2.368	1.021
Unkety Brook	-	0.109	0.051	-	0.059
Nashua River Main Stem 1	-	0.012	-	-	0.012
Nashua River Main Stem Total	**3.819**	**6.811**	**6.076**	**7.632**	**4.548**
NASHUA W/OUT WORCESTER & MWRA	**27.41**	**25.62**	**32.17**	**33.57**	**(0.39)**
NASHUA TOTAL	**183.45**	**25.62**	**32.17**	**33.57**	**(156.43)**

NOTE: TOTAL BALANCE = -AMOUNT WITHDRAWN + AMOUNT DISTRIBUTED - AMOUNT COLLECTED + AMOUNT DISCHARGED

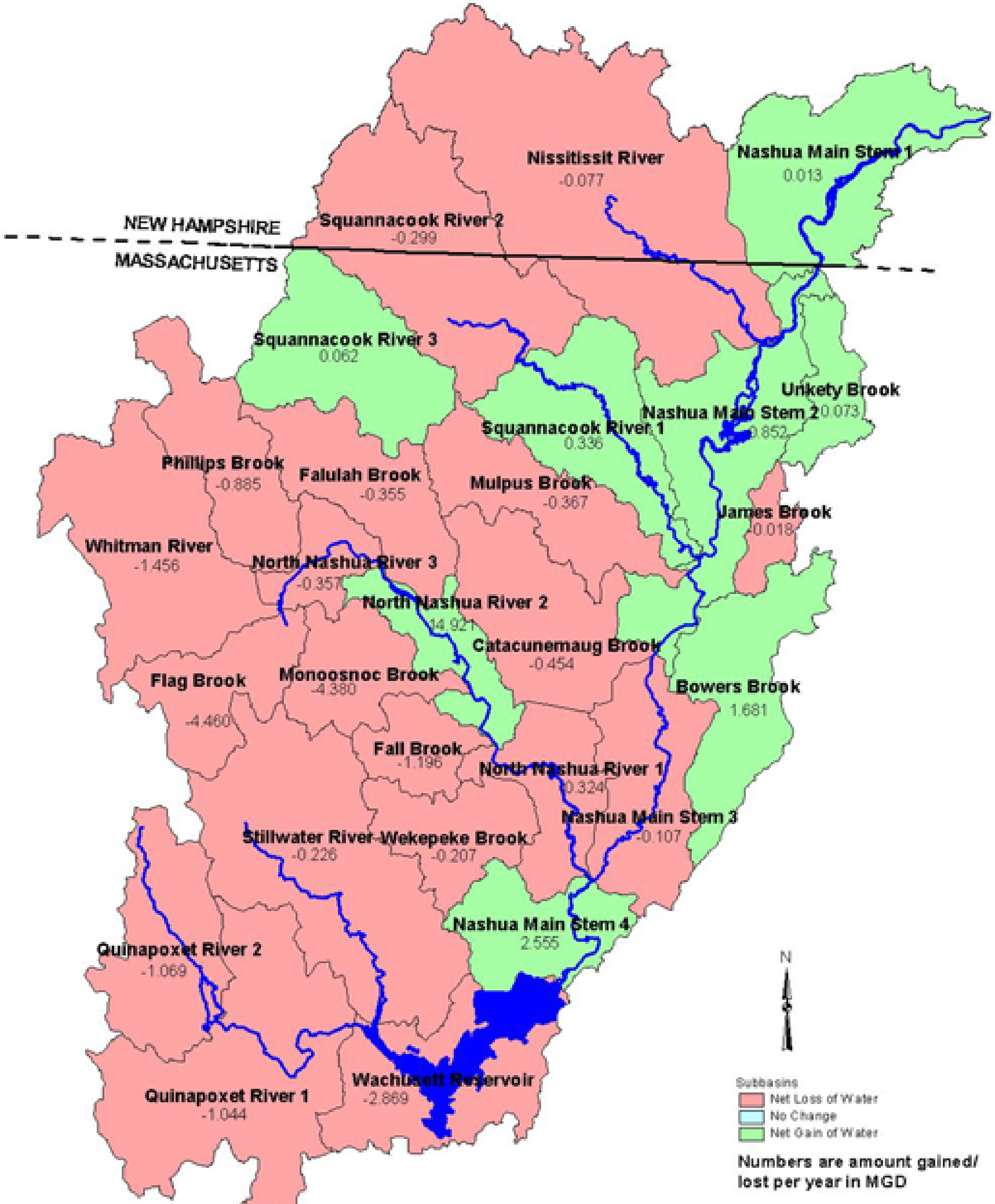


Figure 6-6
Average 2020 Nashua River Watershed Water Balance

CDM

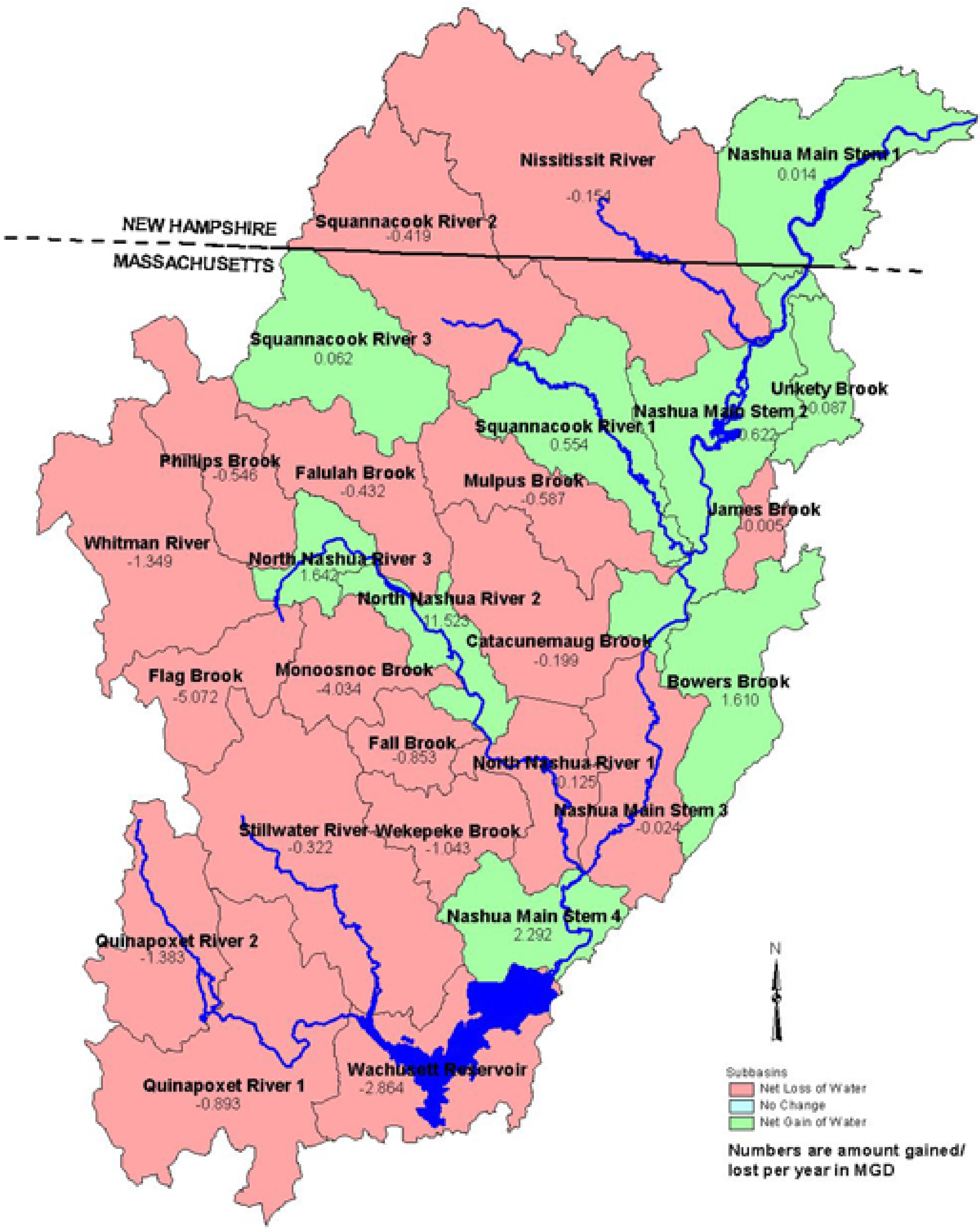


Figure 6-7
August 2020 Nashua River Watershed Water Balance

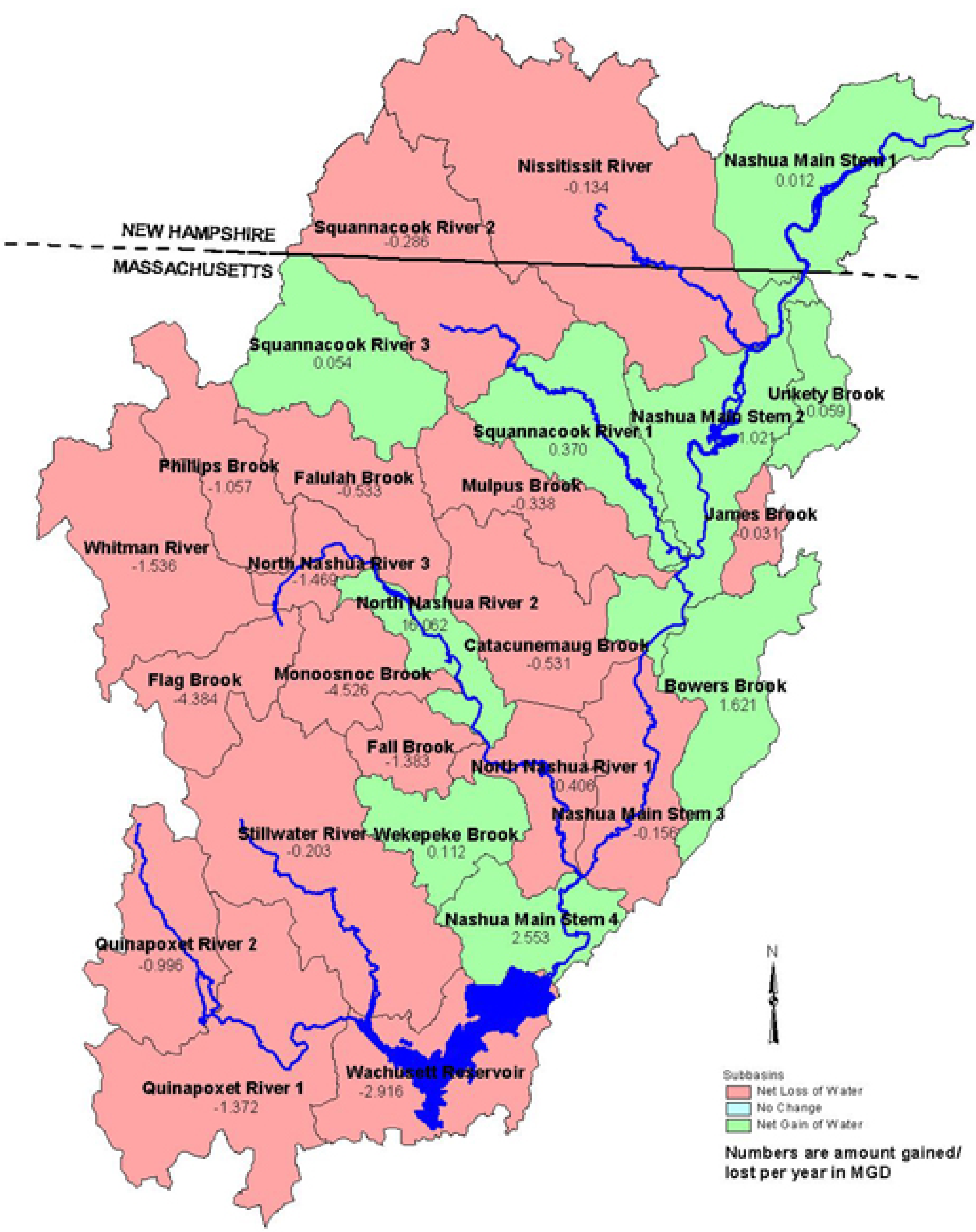


Figure 6-8
Winter 2020 Nashua River Watershed Water Balance

CDM

The general trend throughout the Nashua Watershed is toward increased demands from both groundwater and stream sources, which then get concentrated in wastewater collection systems and passed downstream to wastewater treatment plant discharges. Subareas predicted to be particularly stressed include Falulah Brook, Catacunemaug Brook, Mulpus Brook, and Bower Brook. The predicted increase in losses from these subareas is largely due to increased sewerage and/or population growth in Lunenburg and Ayer.

6.5.2 August 2020

- For this scenario, there is a net loss of 1.9 mgd for the Nashua River watershed or a net loss of 167.4 mgd if MWRA's and Worcester's withdrawals are included.

- Excluding Worcester's and MWRA's large water withdrawals (167.4 mgd) the net loss of water in the watershed is from the difference in water withdrawn (34.3 mgd) to water distributed (30.2 mgd), a loss of 4.1 mgd from the watershed.

- The amount of wastewater discharged, 26.9 mgd, is greater than the amount of wastewater collected, 24.7 mgd, for a gain of 2.2 mgd. Hence, there is a net loss of 1.9 mgd from the watershed.

- Water withdrawn (34.3 mgd) predicted in 2020 will increase by 4.5 mgd over the August 2000 amount withdrawn (29.8 mgd), primarily to meet the increase in water demand.

- Wastewater collection increases from 20.3 mgd in 2000 to 24.7 mgd in 2020, an increase of 4.4 mgd.

- Of the 27 subareas in the watershed, nine have a net gain of water, and 18 subareas have a loss of water.

- A comparison of the 2000 inflow/outflow to the 2020 inflow/outflow is presented in Table 6-15.

Table 6-15
Change in Water Balance
2000 - 2020

	2000 Annual Water Balance	2020 Annual Water Balance	Change in Balance	August 2000 Water Balance	August 2020 Water Balance	Change in Balance	Winter 2000 Water Balance	Winter 2020 Water Balance	Change in Balance
Wachusett Watershed									
Quinapoxet River 2	(0.825)	(1.069)	(0.245)	(0.993)	(1.383)	(0.390)	(0.627)	(0.996)	(0.368)
Worcester Withdrawal[1]	(9.215)	(9.573)	(0.358)	(16.817)	(17.470)	(0.653)	(7.740)	(8.041)	(0.301)
Quinapoxet River 1	(0.561)	(1.044)	(0.484)	(0.379)	(0.893)	(0.514)	(0.711)	(1.372)	(0.661)
Stillwater River	(0.008)	(0.226)	(0.218)	(0.083)	(0.322)	(0.239)	0.003	(0.203)	(0.206)
Wachusett Reservoir	(2.019)	(2.869)	(0.850)	(2.181)	(2.864)	(0.683)	(2.014)	(2.916)	(0.902)
MWRA Withdrawal from Wachusett[2]	(148.000)	(148.000)	-	(148.000)	(148.000)	-	(148.000)	(148.000)	-
Wachusett Total	**(160.627)**	**(162.781)**	**(2.154)**	**(168.454)**	**(170.932)**	**(2.478)**	**(159.090)**	**(161.528)**	**(2.438)**
North Nashua River Watershed									
Phillips Brook	(0.893)	(0.885)	0.008	(0.551)	(0.546)	0.005	(1.067)	(1.057)	0.010
Whitman River	(0.970)	(1.456)	(0.486)	(0.833)	(1.349)	(0.516)	(1.027)	(1.536)	(0.510)
Flag Brook	(4.060)	(4.460)	(0.400)	(4.624)	(5.072)	(0.448)	(3.980)	(4.384)	(0.404)
North Nashua River 3	(1.318)	(0.357)	0.961	0.645	1.642	0.997	(2.472)	(1.469)	1.003
Monoosnoc Brook	(3.418)	(4.380)	(0.962)	(3.140)	(4.034)	(0.894)	(3.547)	(4.526)	(0.979)
Falulah Brook	(0.319)	(0.355)	(0.037)	(0.431)	(0.432)	(0.001)	(0.469)	(0.533)	(0.064)
North Nashua River 2	13.441	14.921	1.480	10.247	11.523	1.276	14.569	16.062	1.493
Fall Brook	(0.937)	(1.196)	(0.260)	(0.670)	(0.853)	(0.183)	(1.082)	(1.383)	(0.300)
Wekepeke Brook	(0.185)	(0.207)	(0.022)	(0.838)	(1.043)	(0.205)	0.067	0.112	0.045
North Nashua River 1	(0.262)	(0.324)	(0.061)	(0.102)	(0.125)	(0.023)	(0.328)	(0.406)	(0.077)
North Nashua River Total	**1.078**	**1.300**	**0.221**	**(0.298)**	**(0.290)**	**0.008**	**0.663**	**0.880**	**0.217**
Squannacook River Watershed									
Squannacook River 3	0.060	0.062	0.002	0.059	0.062	0.002	0.052	0.054	0.002
Squannacook River 2	(0.194)	(0.299)	(0.105)	(0.271)	(0.419)	(0.148)	(0.185)	(0.286)	(0.101)
Squannacook River 1	0.179	0.336	0.157	0.438	0.554	0.116	0.221	0.370	0.148
Mulpus Brook	(0.384)	(0.367)	0.018	(0.568)	(0.587)	(0.019)	(0.357)	(0.338)	0.019
Squannacook River Total	**(0.340)**	**(0.268)**	**0.071**	**(0.342)**	**(0.391)**	**(0.049)**	**(0.268)**	**(0.200)**	**0.068**
Nissitissit River Watershed									
Nissitissit River	(0.061)	(0.077)	(0.016)	(0.108)	(0.154)	(0.046)	(0.096)	(0.134)	(0.038)
Nissitissit River Total	**(0.061)**	**(0.077)**	**(0.016)**	**(0.108)**	**(0.154)**	**(0.046)**	**(0.096)**	**(0.134)**	**(0.038)**
Nashua River Main Stem									
Nashua River Main Stem 4	2.296	2.555	0.260	2.080	2.292	0.212	2.291	2.553	0.262
Nashua River Main Stem 3	(0.094)	(0.107)	(0.014)	(0.017)	(0.024)	(0.008)	(0.140)	(0.156)	(0.016)
Bowers Brook	0.948	1.681	0.733	0.889	1.610	0.721	0.918	1.621	0.703
Catacunemaug Brook	(0.292)	(0.454)	(0.162)	(0.099)	(0.199)	(0.101)	(0.349)	(0.531)	(0.182)
James Brook	(0.011)	(0.018)	(0.008)	(0.003)	(0.005)	(0.002)	(0.018)	(0.031)	(0.013)
Nashua River Main Stem 2	0.551	0.852	0.301	0.417	0.622	0.206	0.724	1.021	0.298
Unkety Brook	0.046	0.073	0.027	0.055	0.087	0.033	0.037	0.059	0.022
Nashua River Main Stem 1	0.008	0.013	0.005	0.009	0.014	0.005	0.007	0.012	0.004
Nashua River Main Stem Total	**3.452**	**4.594**	**1.142**	**3.331**	**4.397**	**1.066**	**3.471**	**4.548**	**1.078**
NASHUA W/OUT WORCESTER & MWRA	**0.717**	**0.340**	**(0.378)**	**(1.054)**	**(1.900)**	**(0.846)**	**0.421**	**(0.393)**	**(0.813)**
NASHUA TOTAL	**(156.497)**	**(157.233)**	**(0.736)**	**(165.871)**	**(167.370)**	**(1.499)**	**(155.320)**	**(156.434)**	**(1.114)**

Section 7
Virgin Flow Analysis

7.1 General

This section presents the results of a virgin flow analysis for the Nashua River Watershed and its subareas. Virgin flows were calculated for the 7Q10, average annual, average August, and average winter conditions for each subarea. Average values for river flows were calculated and used in conjunction with DEM's stressed basin guidelines, which use average flows. Section 7.2 presents the methodology used in calculating the virgin flow for each subarea. Section 7.3 presents the results of the analysis, presenting the predicted virgin flow of each subarea.

7.2 Methodology

The collected flow data and statistics were used to calculate existing flow at each of the continuous gages in the Nashua River Watershed. The existing flows for each gage were presented in Table 2-12. To calculate the virgin flow, the subareas contributing to each USGS gauging station were determined, the net water balance for these subareas was calculated and applied to the USGS gage, and virgin flows at the gauging station were apportioned to each subarea based on the relative sizes of the subareas.

This method, because it uses historical flow data, doesn't account for changes in river flow from changes in impervious areas in the future. Increasing impervious areas decreases groundwater recharge, which in turn, can reduce low flow in rivers and streams.

The method employed is as follows:

STEP 1: DETERMINE SUBAREAS CONTRIBUTING TO USGS GAGES

- Locations of the continuous USGS flow gages were presented in Section 2.

- Subareas upstream of a flow gage contribute flow to that gage.

- If a gage was located within a subarea, as often happened, the subarea containing the gage was subdivided to obtain a fraction of the subarea that contributed flow to the gage. This was done by delineating the area contributing flow to the gage from within the subarea and dividing that area by the total area of the subarea.

- Most subareas contribute to multiple USGS gages, i.e., there is another USGS gage downstream of an existing gage. In all cases, the most applicable USGS gage was assumed to be the most upstream gage that received flow from the subarea. The subareas used for calculations for each USGS gage are presented in Figure 7-1.

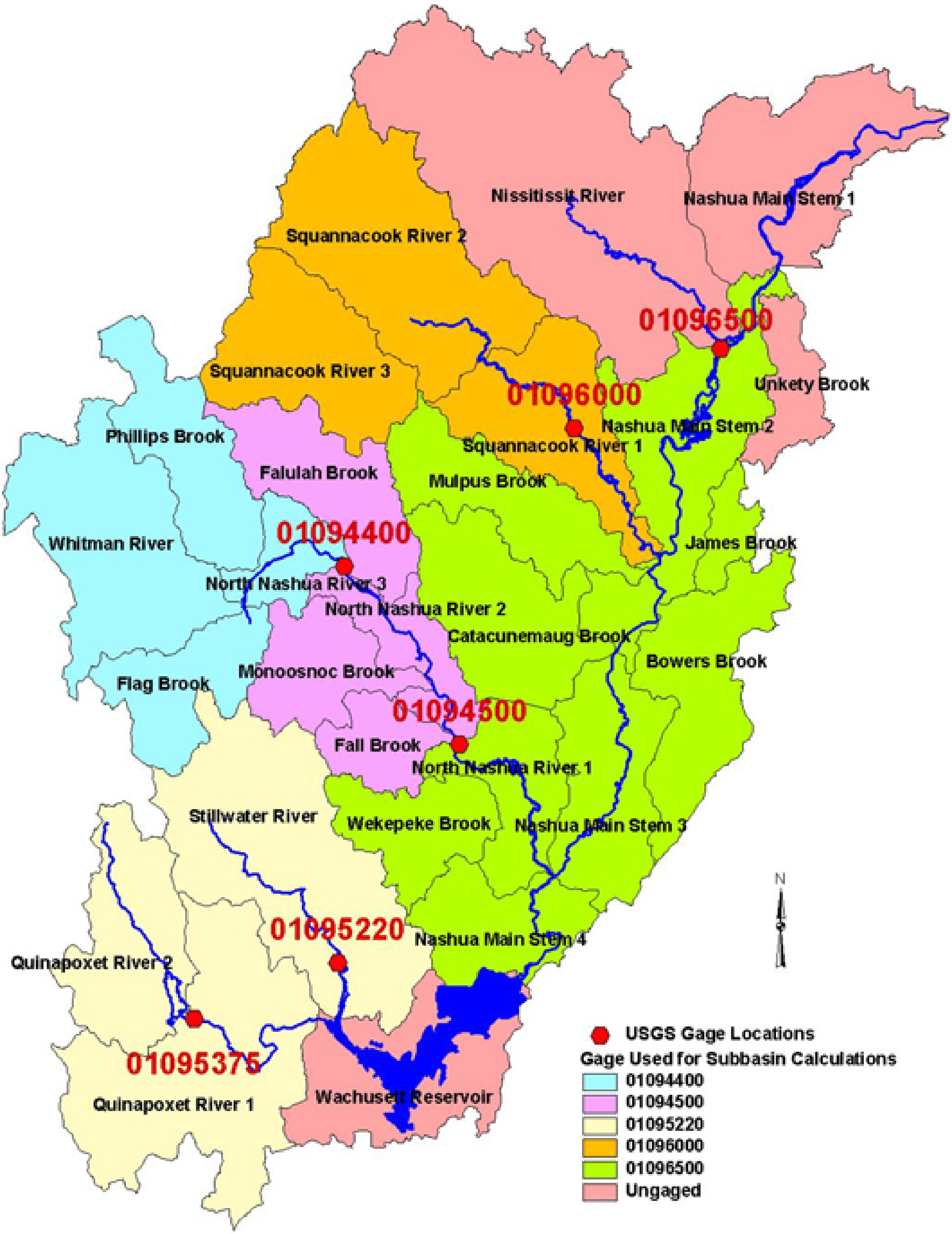


Figure 7-1
USGS Gauges and Basis for Virgin Yield Calculations

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STEP 2: CALCULATE VIRGIN FLOW FOR USGS GAGES

- The subarea Inflow / Outflow values for each subarea contributing to a USGS gage were summed to obtain a total Inflow / Outflow value to be applied to each USGS gage watershed. In the case of subareas that did not entirely contribute to the USGS gage, the amount of the Inflow / Outflow value for that subarea was multiplied by the fraction (which is less than 1) calculated in step 1 for that subarea. This was done for each scenario: average annual, average August, and average winter. Note that the average August inflow / outflow was used to calculate 7Q10 flows.

- Virgin flows were calculated for each USGS gage by using the water balance for each scenario: the average annual 2000 water balance was used for average annual flows, the 2000 August water balance was used for both the average August flows and the 7Q10 flows, and the 2000 winter water balance was used for the average winter flows. Any deficit in the water balance was added to the existing flows, and any surplus in the water balance was subtracted from the existing flows to determine the virgin flow conditions.

- In cases where multiple gages metered the same subareas, the virgin flow was calculated for the upstream gage watershed first, using the upstream USGS gage. The virgin flow of the downstream subareas was then calculated to be the virgin flow of the entire downstream gage watershed (which includes the upstream subareas) minus the virgin flow of the upstream gage watershed. The subbasins used for each USGS gage were presented in Figure 7-1.

- In the case of the North Nashua River Watershed, there are numerous multi-month reservoirs that enable increased withdrawal during low flow periods, such as August. Therefore, it is not appropriate to calculate virgin low flows using the results of the August Inflow / Outflow analysis—doing this could substantially overestimate the virgin flows in the basin. Therefore, to calculate virgin low flows (7Q10 and Average August) in the North Nashua River watershed, an assumption was made that the existing stream flow equals virgin flow plus wastewater discharge, i.e. the wastewater flow (resulting from the use of multi-month reservoirs) supplements flow to the stream. Therefore, the August wastewater discharge was subtracted from the existing flow at the USGS gage, to obtain virgin stream flow at the gage. This may be only an approximate method. Upstream reservoirs may hold back and store all inflow, which would reduce current stream flow below the estimated virgin flow.

STEP 3: CALCULATE VIRGIN FLOW FOR SUBAREAS

- The virgin flow for each subarea was calculated based on the virgin flow for the applicable USGS gage, using the flow per unit area of the USGS gage times the area of the individual subarea.

- Four subareas could not be calculated directly from gaging data because they did not contribute directly to USGS gages: Wachusett Reservoir, Nissitissit River, Unkety Brook, and Nashua River main Stem 1. In each of these cases, subareas with similar levels of development and similar position (upstream / downstream) in the watershed were used to determine flow from these subareas: Stillwater River was used for Wachusett Reservoir, Squannacook River 2 was used for Nissitissit River, James Brook was used for Unkety Brook, and Nashua River Main Stem 2 was used for Nashua River Main Stem 1. For each of these subareas, a flow per unit area from the similar subarea was used as the basis for calculating the unknown virgin flows.

7.3 Subarea Flows

The calculations and resulting values for subarea virgin flows under 7Q10 conditions are presented in Table 7-1. Table 7-2 presents the average August virgin flows. Table 7-3 presents the average annual virgin flows, and average winter virgin flows are presented in Table 7-4.

7.4 Aquifer Yields

Information on aquifer yields is available for six aquifers in the Nashua River watershed. The USGS prepared a report: *Stream-Aquifer Relations and Yields of Stratified-Drift Aquifers in the Nashua River Basin*, Report No. 88-4147. In this report, the USGS estimated the aquifer yield for the following aquifers:

- Pearl Hill-Willard Brooks
- Stillwater River
- Wekepeke Brook
- Still River
- Witch Brook
- Catacunemaug Brook

Each of these stratified-drift aquifers is currently used for water supply and has been identified as a possible source of additional supply for communities in the watershed.

Short-term and long-term yields from groundwater discharge and infiltration of surface water were estimated by the USGS for each of the aquifers. Estimates of potential short-term aquifer yield were made by withdrawing water from aquifer storage. The report also estimated long-term aquifer yields that maintained stream flows 99.5% of the time. Table 7-5 presents the estimated short-term and long-term aquifer yields for each of the six aquifers. The Year 2000 August and Annual withdrawals from the aquifers are also presented. Table 7-5 indicates several of the aquifers have withdrawals that exceed the maximum long-term withdrawals.

Table 7-1
Calculation of 7Q10 Virgin Flows

USGS Gage/ Subarea	Drainage Area (mi^2)	7Q10 Gage Flow (cfs)	Gage Flow (MGD)	Inflow/Outflow (MGD)	Virgin Flow (MGD)	Virgin Flow per Unit Area (MGD/mi^2)	Virgin Flow per Unit Area (cfs/mi^2)
1095220	**31.6**	**0.64**	**0.41**	**-0.067**	**0.48**	**0.015**	**0.024**
Stillwater River	39.3			-0.083	0.60	0.015	0.024
1094500	**110**	**32.81**	**21.21**	**15.200**	**6.01**	**0.055**	**0.084**
Phillips Brook	15.8				0.86	0.055	0.084
Whitman River*	28.4				1.55	0.055	0.084
Flag Brook*	12.6				0.69	0.055	0.084
North Nashua River 3	6.8			4.950	0.37	0.055	0.084
Falulah Brook*	16.1				0.88	0.055	0.084
Monoosnoc Brook*	11.4				0.62	0.055	0.084
Fall Brook*	7.2				0.39	0.055	0.084
North Nashua River 2	9.5			10.250	0.52	0.055	0.084
1096000	**63.7**	**6.53**	**4.22**	**0.226**	**3.99**	**0.063**	**0.097**
Squannacook River 3	20.2			0.059	1.27	0.063	0.097
Squannacook River 2	33.3			-0.271	2.09	0.063	0.097
Squannacook River 1	19.6			0.438	1.23	0.063	0.097
1096500	**316**	**44.45**	**28.73**	**17.185**	**11.55**	**0.037**	**0.057**
01094500 results	110			15.20	6.01	0.055	0.084
01096000 results	63.7			0.23	3.99	0.063	0.097
Nashua River Main Stem 2	27.2			0.417	0.30	0.011	0.017
Nashua River Main Stem 3	17.8			-0.017	0.19	0.011	0.017
Nashua River Main Stem 4	12.7			2.080	0.14	0.011	0.017
Wekepeke Brook*	11.6			-0.838	0.13	0.011	0.017
North Nashua River 1	12.6			-0.102	0.14	0.011	0.017
Catacunemaug Brook*	20.0			-0.099	0.22	0.011	0.017
Bowers Brook	18.8			0.889	0.20	0.011	0.017
Mulpus Brook*	15.9			-0.568	0.17	0.011	0.017
James Brook	3.9			-0.003	0.04	0.011	0.017
Ungaged							**0.000**
Quinapoxet River 1	37.28				0.57	0.015	0.024
Quinapoxet River 2	18.11				0.28	0.015	0.024
Wachusett Reservoir	23.47				0.36	0.015	0.024
Unkety Brook	6.86				0.25	0.037	0.057
Nissitissit River	60.99				3.82	0.063	0.097
Nashua River Main Stem 1	26.35				0.96	0.037	0.057

North Nashua River wastewater discharges were used in lieu of Inflow/Outflows because of the impact of multi-month reservoirs

* Subbasin contains a multi-month reservoir and may have adverse impact on Virgin Yield calculation

Table 7-2
Calculation of Average August Virgin Flows

USGS Gage/ Subarea	Drainage Area (mi^2)	Average August Gage Flow (cfs)	Gage Flow (MGD)	Inflow/Outflow (MGD)	Virgin Flow (MGD)	Virgin Flow per Unit Area (MGD/mi^2)	Virgin Flow per Unit Area (cfs/mi^2)
1095220	**31.6**	**9.24**	**5.97**	**-0.067**	**6.04**	**0.191**	**0.296**
Stillwater River	39.3			-0.083	7.52	0.191	0.296
1094500	**110**	**80.93**	**52.31**	**15.200**	**37.11**	**0.337**	**0.522**
Phillips Brook	15.8				5.32	0.337	0.522
Whitman River*	28.4				9.58	0.337	0.522
Flag Brook*	12.6				4.25	0.337	0.522
North Nashua River 3	6.8			4.950	2.28	0.337	0.522
Falulah Brook*	16.1				5.42	0.337	0.522
Monoosnoc Brook*	11.4				3.84	0.337	0.522
Fall Brook*	7.2				2.43	0.337	0.522
North Nashua River 2	9.5			10.250	3.19	0.337	0.522
1096000	**63.7**	**29.02**	**18.76**	**0.226**	**18.53**	**0.291**	**0.450**
Squannacook River 3	20.2			0.059	5.88	0.291	0.450
Squannacook River 2	33.3			-0.271	9.69	0.291	0.450
Squannacook River 1	19.6			0.438	5.71	0.291	0.450
1096500	**316**	**212.82**	**137.57**	**17.185**	**120.38**	**0.381**	**0.589**
01094500 results	110			15.20	37.11	0.337	0.522
01096000 results	63.7			0.23	18.53	0.291	0.450
Nashua River Main Stem 2	27.2			0.417	12.37	0.455	0.704
Nashua River Main Stem 3	17.8			-0.017	8.11	0.455	0.704
Nashua River Main Stem 4	12.7			2.080	5.76	0.455	0.704
Wekepeke Brook*	11.6			-0.838	5.25	0.455	0.704
North Nashua River 1	12.6			-0.102	5.74	0.455	0.704
Catacunemaug Brook*	20.0			-0.099	9.10	0.455	0.704
Bowers Brook	18.8			0.889	8.57	0.455	0.704
Mulpus Brook*	15.9			-0.568	7.23	0.455	0.704
James Brook	3.9			-0.003	1.77	0.455	0.704
Ungaged							**0.000**
Quinapoxet River 1	37.28				7.12	0.191	0.296
Quinapoxet River 2	18.11				3.46	0.191	0.296
Wachusett Reservoir	23.47				4.48	0.191	0.296
Unkety Brook	6.86				2.61	0.381	0.589
Nissitissit River	60.99				17.75	0.291	0.450
Nashua River Main Stem 1	26.35				10.04	0.381	0.589

North Nashua River wastewater discharges were used in lieu of Inflow/Outflows because of the impact of multi-month reservoirs

* Subbasin contains a multi-month reservoir and may have adverse impact on Virgin Yield calculation

Table 7-3
Calculation of Average Annual Virgin Flows

USGS Gage/ Subarea	Drainage Area (mi^2)	Average Annual Gage Flow (cfs)	Gage Flow (MGD)	Inflow/Outflow (MGD)	Virgin Flow (MGD)	Virgin Flow per Unit Area (MGD/mi^2)	Virgin Flow per Unit Area (cfs/mi^2)
1095220	**31.6**	**54.78**	**35.41**	**-0.006**	**35.42**	**1.121**	**1.734**
Stillwater River	39.3			-0.008	44.08	1.12	1.73
1094400	**63.4**	**122.29**	**79.05**	**-7.242**	**86.29**	**1.36**	**2.11**
Phillips Brook	15.8			-0.893	21.48	1.36	2.11
Whitman River*	28.4			-0.970	38.63	1.36	2.11
Flag Brook*	12.6			-4.060	17.16	1.36	2.11
North Nashua River 3	6.8			-1.318	9.19	1.36	2.11
1094500	**110**	**200.26**	**129.45**	**8.767**	**34.39**	**0.31**	**0.48**
1094400 results	63.4				86.29	1.36	2.11
Falulah Brook*	16.1			-0.319	5.02	0.31	0.48
Monoosnoc Brook*	11.4			-3.418	3.56	0.31	0.48
Fall Brook*	7.2			-0.937	2.25	0.31	0.48
North Nashua River 2	9.5			13.441	2.95	0.31	0.48
1096000	**63.7**	**113.31**	**73.25**	**0.045**	**73.20**	**1.15**	**1.78**
Squannacook River 3	20.2			0.060	23.22	1.15	1.78
Squannacook River 2	33.3			-0.194	38.26	1.15	1.78
Squannacook River 1	19.6			0.179	22.56	1.15	1.78
1096500	**316**	**583.52**	**377.19**	**2.567**	**180.74**	**0.57**	**0.88**
01094400 results	63.4				86.29	1.36	2.11
01095500 results	110				34.39	0.31	0.48
01096000 results	63.7				73.20	1.15	1.78
Nashua River Main Stem 2	27.2			0.551	15.55	0.57	0.88
Nashua River Main Stem 3	17.8			-0.094	10.20	0.57	0.88
Nashua River Main Stem 4	12.7			2.296	7.24	0.57	0.88
Wekepeke Brook*	11.6			-0.185	6.61	0.57	0.88
North Nashua River 1	12.6			-0.262	7.21	0.57	0.88
Catacunemaug Brook*	20.0			-0.292	11.45	0.57	0.88
Bowers Brook	18.8			0.948	10.77	0.57	0.88
Mulpus Brook*	15.9			-0.384	9.09	0.57	0.88
James Brook	3.9			-0.011	2.23	0.57	0.88
Ungaged							
Quinapoxet River 1	37.28				41.78	1.12	1.73
Quinapoxet River 2	18.11				20.30	1.12	1.73
Wachusett Reservoir	23.47				26.30	1.12	1.73
Unkety Brook	6.86				3.92	0.57	0.88
Nissitissit River	60.99				70.09	1.15	1.78
Nashua River Main Stem 1	26.35				15.07	0.57	0.88

* Subbasin contains a multi-month reservoir and may have adverse impact on Virgin Yield calculation

Table 7-4
Calculation of Average Winter Virgin Flows

USGS Gage/ Subarea	Drainage Area (mi^2)	Average Winter Gage Flow (cfs)	Gage Flow (MGD)	Inflow/Outflow (MGD)	Virgin Flow (MGD)	Virgin Flow per Unit Area (MGD/mi^2)	Virgin Flow per Unit Area (cfs/mi^2)
1095220	**31.6**	**87.14**	**56.33**	**0.002**	**56.33**	**1.782**	**2.757**
Stillwater River	39.3			0.003	70.10	1.78	2.76
1094400	**63.4**	**141.64**	**91.56**	**-8.546**	**100.11**	**1.58**	**2.44**
Phillips Brook	15.8			-1.067	24.92	1.58	2.44
Whitman River*	28.4			-1.027	44.81	1.58	2.44
Flag Brook*	12.6			-3.980	19.91	1.58	2.44
North Nashua River 3	6.8			-2.472	10.66	1.58	2.44
1094500	**110**	**217.19**	**140.39**	**9.470**	**30.82**	**0.28**	**0.43**
1094400 results	63.4				100.11	1.58	2.44
Falulah Brook*	16.1			-0.469	4.50	0.28	0.43
Monoosnoc Brook*	11.4			-3.547	3.19	0.28	0.43
Fall Brook*	7.2			-1.082	2.01	0.28	0.43
North Nashua River 2	9.5			14.569	2.65	0.28	0.43
1096000	**63.7**	**126.83**	**81.98**	**0.089**	**81.89**	**1.29**	**1.99**
Squannacook River 3	20.2			0.052	25.98	1.29	1.99
Squannacook River 2	33.3			-0.185	42.80	1.29	1.99
Squannacook River 1	19.6			0.221	25.24	1.29	1.99
1096500	**316**	**634.27**	**410.00**	**2.809**	**194.38**	**0.62**	**0.95**
01094400 results	63.4				100.11	1.58	2.44
01095500 results	110				30.82	0.28	0.43
01096000 results	63.7				81.89	1.29	1.99
Nashua River Main Stem 2	27.2			0.724	16.72	0.62	0.95
Nashua River Main Stem 3	17.8			-0.140	10.97	0.62	0.95
Nashua River Main Stem 4	12.7			2.291	7.79	0.62	0.95
Wekepeke Brook*	11.6			0.067	7.10	0.62	0.95
North Nashua River 1	12.6			-0.328	7.76	0.62	0.95
Catacunemaug Brook*	20.0			-0.349	12.31	0.62	0.95
Bowers Brook	18.8			0.918	11.58	0.62	0.95
Mulpus Brook*	15.9			-0.357	9.78	0.62	0.95
James Brook	3.9			-0.018	2.40	0.62	0.95
Ungaged							
Quinapoxet River 1	37.28				66.45	1.78	2.76
Quinapoxet River 2	18.11				32.28	1.78	2.76
Wachusett Reservoir	23.47				41.83	1.78	2.76
Unkety Brook	6.86				4.22	0.62	0.95
Nissitissit River	60.99				78.41	1.29	1.99
Nashua River Main Stem 1	26.35				16.21	0.62	0.95

* Subbasin contains a multi-month reservoir and may have adverse impact on Virgin Yield calculation

Table 7-5

Aquifer Withdrawal Assessment

Aquifer	Drainage Area (square miles)	Maximum Short[1] Term Aquifer Withdrawal (MGD)	Maximum Long[2] Term Aquifer Withdrawal (MGD)	Year 2000 August Withdrawal (MGD)	Year 2000 Annual Withdrawal (MGD)
Pearl Hill-Willard Brooks	42.3	5.8	0.45	0.3	0.25
Stillwater River	31.6	10.3	0.33	0.59	0.47
Wekepeke Brook	11.6	6.6	0.42	1.59	0.52
Still River	4.2	13.1	0.58	1.05	0.71
Catacunemaug	19.1	10.3	1.09	0.43	0.36
Witch Brook	5.1	10.3	0.07	0.47	0.34

Notes: 1) Available by drawing down the aquifer
2) Max. withdrawal while maintaining stream flow at 99% duration (approx. 7Q10)

From: Stream-Aquifer relations and Yield of Stratified-Drift Aquifers in the Nashua River Basin, USGS Report 88-4147

Table 7-6
Community Withdrawals

Aquifer	Community	Annual Withdrawal (MGD)
Pearl Hill-Willard Brook	Townsend	0.25
Stillwater River	Sterling	0.47
Wekepeke Brook	Leominster Lancaster Sterling	0.52 0.0 0.0
Witch Brook	Townsend	0.34
Catacunemaug Brook	Lunenburg Lancaster	0.36 0.0
Still River	Bolton Lancaster	0.16 0.55

Section 8
Subarea Flow and Stream Flow Changes

8.1 General

This section combines the results of the Inflow / Outflow Analysis and the Virgin Flow Analysis to determine overall changes in stream flow in the Nashua River Watershed from virgin conditions to existing and future conditions. Changes in flow were calculated for the 7Q10, average annual, average August, and average winter conditions.

8.2 Methodology

Much of this analysis is based on Section 6: Subarea Inflow / Outflow Analysis and Section 7: Virgin Flow Analysis. The Inflow / Outflow Analysis determined the net water balance for each subbasin on an average annual, average August, and average Winter basis. The water balance was calculated by subtracting the outflows from the basin (water withdrawn and wastewater collected) from the inflows (water distribution and wastewater discharged). The Virgin Flow Analysis built upon the Inflow / Outflow Analysis by combining existing flow data and the individual water balances for each subbasin to calculate virgin flow conditions for the average annual, average August, average winter, and 7Q10 flow conditions.

- Two types of flows are considered in this analysis: subarea flows and stream flows. Subarea flows are the amount of flow that a subarea would contribute to the total stream flow. In some of the calculations, the subarea flow was determined to be negative; in such cases, there was no net contribution to stream flow from the given subarea.

- Stream flows were calculated as the predicted total flow in the rivers resulting from subarea inflows; stream flows were never negative.

Virgin flows are the predicted flows that would be released from each subarea prior to development. Existing flows were determined based on USGS metering data in the Nashua River Basin. For more information about the Virgin Flow Analysis, please refer to Section 7.

STEP 1: CALCULATE EXISTING FLOW FOR SUBAREAS

- After calculating the virgin flow for each subarea, the results of the Inflow / Outflow analysis for each subarea were used to calculate the existing flow for each subarea. Note that it was not possible to directly determine the existing flow for each subarea because the subareas were not individually gaged, and water withdrawals and discharges are not evenly spread between the subareas. Therefore, it was necessary to calculate a virgin flow that was generally applicable (as a flow per unit area) to multiple subareas, and then to calculate the existing flow based on the results of the inflow / outflow analysis for each subarea.

- In some cases, calculated existing flows are negative during low flow (7Q10) conditions. This can be the result of two factors: (1) if the subarea contains multi-month reservoirs, then the inflow / outflow analysis is not sufficient for this subarea because the reservoirs can store flows from higher flow periods for use in periods of low flow, or (2) if there are not substantial reservoirs, there would be a net loss of water from the subarea, indicating that stored groundwater was being used, and the water table was being drawn down. Under these conditions, no significant flow would be expected in the stream.

  In most cases in this study, negative existing flows were the result of reservoirs in the subarea. In order to determine the potential stresses of water withdrawal in these basins, a more detailed study would be required, particularly to study the management of these reservoirs.

STEP 2: CALCULATE FUTURE FLOW FOR SUBBASINS

This involved the same procedures as step 4, using the results of the future (2020) inflow / outflow analysis.

STEP 3: CALCULATE STREAM FLOW

In this analysis, the flows from each subarea were summed from upstream to downstream, to obtain the total change in flow in each of the major branches of the Nashua River.

- For each basin the virgin, existing, or future flow were added to the stream flow to calculate the total stream flow at a given location. If the flow for any particular subarea was negative, it was considered to contribute no flow to the stream. No flow was subtracted from the stream flow in such cases (i.e. the subbasin flow was considered to be 0).

- It was not possible to calculate reliable existing 7Q10 and average August flows for the North Nashua River upstream of the USGS gages because of the presence of multi-month reservoirs and their impact on the reliability of the existing flow of each subarea. Therefore, the existing flow in the North Nashua River was set equal to the average gage readings for 7Q10 and average August flows, and the inflow from each subarea upstream of the gages was not considered (the existing flow was generally negative in these subareas).

The results of this stream flow analysis were compiled into schematic figures (Figures 8-1 through 8-8, described later in this section) showing the stream flow from upstream to downstream in each major river stretch—Nashua River Main Stem (including Wachusett Reservoir), North Nashua River, and the Squannacook River. The distance between tributaries is shown in a relative manner. In each of the figures, there are three curves: virgin flow, existing flow, and wastewater flow. Each of these values are based on the calculations performed in Sections 6 and 7.

8.3 Subarea Flow Impacts

Based on the calculations described in Section 8.2, subarea flows were calculated for the virgin, existing (2000), and future (2020) scenarios under 7Q10, Average August, Average Annual, and Average Winter conditions.

8.3.1 7Q10 and Average August Flows

Table 8-1 presents the virgin, existing, and future 7Q10 flows for each subarea. Table 8-2 presents these flows for the average August scenario.

Wachusett Watershed

The total virgin 7Q10 flow from the Wachusett Reservoir Watershed was calculated to be 1.8 mgd, which is equal to the typical release of 1.8 mgd at Wachusett Reservoir. (See Section 7.0 for the development of the virgin flows.) Neglecting the withdrawals of Worcester and the MWRA (both draw water from large reservoirs, and a more detailed analysis would be required to draw conclusions regarding their operations), the existing communities draw more water from the Wachusett subareas than is estimated to be available under 7Q10 conditions. The negative existing flow in these subbasins does not necessarily mean water will not be available for these communities; more likely, it means that these communities will utilize groundwater storage and draw down the water table during these very low flow periods. Stream flow in such cases would be expected to be negligible. In the future, this problem will be exacerbated by additional growth in the watershed. But the 1.8 mgd release requirement for the Wachusett Reservoir will continue.

Under average August conditions, subarea flows in the Wachusett Watershed are expected to be reduced from virgin conditions, but in neither the existing nor the future scenarios are the subarea flows predicted to be negative. This means stream flow will be reduced from virgin flow in the Wachusett Watershed, but there will still be stream flow.

North Nashua River Watershed

The results for the North Nashua River Watershed are largely inconclusive and possibly misleading because most of the upstream subareas contain multi-month reservoirs. Multi-month reservoirs provide stored water during low flow periods, so withdrawals from these reservoirs do not necessarily impact stream flow or groundwater levels during low flow periods. A more detailed analysis would be required to determine potential withdrawal impacts on the North Nashua River Watershed during low flow conditions.

Table 8-1
Virgin, Existing (2000), and Future (2020) 7Q10 Flows

	Virgin 7Q10 Flow (MGD)	Existing (2000) Subbasin Water Balance (MGD)	Existing (2000) 7Q10 Flow (MGD)	Future (2020) Subbasin Water Balance (MGD)	Future (2020) 7Q10 Flow (MGD)
Wachusett Watershed					
Quinapoxet River 2	0.275	(0.993)	(0.718)	(1.383)	(1.107)
Worcester Withdrawal[1]		(16.817)	-	(17.470)	-
Quinapoxet River 1	0.567	(0.379)	0.188	(0.893)	(0.326)
Stillwater River	0.598	(0.083)	0.515	(0.322)	0.276
Wachusett Reservoir	0.357	(2.181)	(1.824)	(2.864)	(2.507)
MWRA Withdrawal from Wachusett[2]		**(148.000)**	**-**	**(148.000)**	**-**
Wachusett Total	**1.798**	**(168.454)**	**(1.839)**	**(170.932)**	**(3.664)**
North Nashua River Watershed					
Phillips Brook	0.862	(0.551)	0.311	(0.546)	0.316
Whitman River[3]	1.550	(0.833)	0.717	(1.349)	0.201
Flag Brook[3]	0.689	(4.624)	(3.935)	(5.072)	(4.383)
North Nashua River 3	0.369	0.645	1.013	1.642	2.010
Monoosnoc Brook[3]	0.622	(3.140)	(2.519)	(4.034)	(3.413)
Falulah Brook[3]	0.877	(0.431)	0.446	(0.432)	0.444
North Nashua River 2	0.516	10.247	10.763	11.523	12.039
Fall Brook[3]	0.393	(0.670)	(0.277)	(0.853)	(0.460)
Wekepeke Brook[3]	0.125	(0.838)	(0.712)	(1.043)	(0.918)
North Nashua River 1	0.137	(0.102)	0.035	(0.125)	0.012
North Nashua River Total	**6.139**	**(0.298)**	**5.841**	**(0.290)**	**5.849**
Squannacook River Watershed					
Squannacook River 3	1.267	0.059	1.327	0.062	1.329
Squannacook River 2	2.088	(0.271)	1.816	(0.419)	1.668
Squannacook River 1	1.231	0.438	1.669	0.554	1.785
Mulpus Brook[3]	0.173	(0.568)	(0.396)	(0.587)	(0.414)
Squannacook River Total	**4.759**	**(0.342)**	**4.416**	**(0.391)**	**4.367**
Nissitissit River Watershed					
Nissitissit River	3.825	(0.108)	3.717	(0.154)	3.671
Nissitissit River Total	**3.825**	**(0.108)**	**3.717**	**(0.154)**	**3.671**
Nashua River Main Stem					
Nashua River Main Stem 4	0.138	2.080	2.217	2.292	2.429
Nashua River Main Stem 3	0.194	(0.017)	0.177	(0.024)	0.169
Bowers Brook	0.205	0.889	1.094	1.610	1.815
Catacunemaug Brook3	0.217	(0.099)	0.119	(0.199)	0.018
James Brook	0.042	(0.003)	0.039	(0.005)	0.037
Nashua River Main Stem 2	0.295	0.417	0.712	0.622	0.917
Unkety Brook	0.251	0.055	0.306	0.087	0.338
Nashua River Main Stem 1	0.963	0.009	0.972	0.014	0.977
Nashua River Main Stem Total	**2.305**	**3.331**	**5.635**	**4.397**	**6.701**
NASHUA W/OUT MWRA AND WORCESTER	**18.825**	**(1.054)**	**17.771**	**(1.900)**	**16.924**
NASHUA TOTAL	**18.825**	**(165.871)**	**17.771**	**(167.370)**	**16.924**

[1] Worcester Withdraws Water from the downstream end of the Quinapoxet 2 Subarea

[2] MWRA Withdraws water from the Downstream end of the Wachusett Watershed

[3] Subarea has use of multi-month reservoirs, thereby requiring more detailed analysis to make conclusions for 7Q10 or August yields. Average annual yield is reliable for these subbasins.

Table 8-2
Average August Virgin, Existing (2000), and Future (2020) Flows

	Virgin August Flow (MGD)	Existing (2000) Subbasin Water Balance (MGD)	Existing (2000) August Flow (MGD)	Future (2020) Subbasin Water Balance (MGD)	Future (2020) August Flow (MGD)
Wachusett Watershed					
Quinapoxet River 2	3.460	(0.993)	2.467	(1.383)	2.078
Worcester Withdrawal[1]	-	(16.817)	-	(17.470)	-
Quinapoxet River 1	7.123	(0.379)	6.744	(0.893)	6.230
Stillwater River	7.515	(0.083)	7.432	(0.322)	7.193
Wachusett Reservoir	4.485	(2.181)	2.304	(2.864)	1.621
MWRA Withdrawal from Wachusett[2]	**-**	**(148.000)**	**-**	**(148.000)**	**-**
Wachusett Total	**22.584**	**(168.454)**	**18.947**	**(170.932)**	**17.122**
North Nashua River Watershed					
Phillips Brook	5.324	(0.551)	4.773	(0.546)	4.778
Whitman River[3]	9.575	(0.833)	8.742	(1.349)	8.226
Flag Brook[3]	4.255	(4.624)	(0.369)	(5.072)	(0.818)
North Nashua River 3	2.277	0.645	2.922	1.642	3.919
Monoosnoc Brook[3]	3.840	(3.140)	0.699	(4.034)	(0.194)
Falulah Brook[3]	5.415	(0.431)	4.985	(0.432)	4.983
North Nashua River 2	3.188	10.247	13.435	11.523	14.712
Fall Brook[3]	2.426	(0.670)	1.756	(0.853)	1.573
Wekepeke Brook[3]	5.254	(0.838)	4.416	(1.043)	4.211
North Nashua River 1	5.736	(0.102)	5.634	(0.125)	5.611
North Nashua River Total	**47.292**	**(0.298)**	**46.994**	**(0.290)**	**47.002**
Squannacook River Watershed					
Squannacook River 3	5.880	0.059	5.940	0.062	5.942
Squannacook River 2	9.686	(0.271)	9.415	(0.419)	9.267
Squannacook River 1	5.711	0.438	6.149	0.554	6.265
Mulpus Brook[3]	7.233	(0.568)	6.665	(0.587)	6.646
Squannacook River Total	**28.511**	**(0.342)**	**28.168**	**(0.391)**	**28.119**
Nissitissit River Watershed					
Nissitissit River	17.745	(0.108)	17.637	(0.154)	17.591
Nissitissit River Total	**17.745**	**(0.108)**	**17.637**	**(0.154)**	**17.591**
Nashua River Main Stem					
Nashua River Main Stem 4	5.759	2.080	7.839	2.292	8.051
Nashua River Main Stem 3	8.111	(0.017)	8.094	(0.024)	8.087
Bowers Brook	8.566	0.889	9.456	1.610	10.176
Catacunemaug Brook3	9.103	(0.099)	9.004	(0.199)	8.903
James Brook	1.774	(0.003)	1.771	(0.005)	1.769
Nashua River Main Stem 2	12.369	0.417	12.786	0.622	12.991
Unkety Brook	2.613	0.055	2.668	0.087	2.701
Nashua River Main Stem 1	10.038	0.009	10.047	0.014	10.052
	58.334	**3.331**	**61.665**	**4.397**	**62.731**
NASHUA W/OUT MWRA AND WORCESTER	**174.465**	**(1.054)**	**173.412**	**(1.900)**	**172.565**
NASHUA TOTAL	**174.465**	**(165.871)**	**173.412**	**(167.370)**	**172.565**

[1] Worcester Withdraws Water from the downstream end of the Quinapoxet 2 Subarea

[2] MWRA Withdraws water from the Downstream end of the Wachusett Watershed

[3] Subarea has use of multi-month reservoirs, thereby requiring more detailed analysis to make conclusions for 7Q10 or August yields. Average annual yield is reliable for these subbasins.

Under average August conditions, problems similar to those affecting 7Q10 flow calculations are encountered, though they aren't as obvious because there are fewer calculations of negative flows in the subareas. However, the actual flow is likely still larger than the flow predicted in Table 8-2 for the North Nashua River subbasins because of the widespread use of multi-month reservoirs in the watershed.

Squannacook and Nissitissit River Watersheds

Based on the results of the inflow / outflow analysis, the Squannacook and Nissitissit Watersheds are predicted to have a net increase in flow in most of their subareas during 7Q10 conditions. The exception to this rule is the Mulpus Brook subarea, which contains a multi-month reservoir, so the negative flow predicted there is misleading. In the future, the increase in flow in the Squannacook River Watershed is predicted to increase, as more water is drawn from neighboring subareas to supply growth in the watershed. The Nissitissit River Watershed is expected to have a smaller net increase in future conditions than existing, but its flow is still predicted to be greater than the virgin flow.

Like the 7Q10 flows in these subareas, the average August flows are expected to increase somewhat from virgin conditions. Overall, the change in flows from these subareas is not predicted to be particularly significant.

Nashua River Main Stem Watershed

Although most of the subareas contributing to the Main Stem of the Nashua River are predicted to have flows reduced from virgin conditions (caused by a negative subarea water balance), the net flow for the Nashua River Main Stem Basins as a whole is expected to increase above virgin 7Q10 conditions because of wastewater discharges, which provide water used both from neighboring watersheds and possibly from multi-month reservoirs as well.

With the exception of wastewater discharge locations, the existing flow is generally marginally lower than the virgin flow in average August conditions.

8.3.2 Average Annual and Average Winter Flow

Tables 8-3 and 8-4 present the results of the flow analysis for Average Annual and Average Winter conditions, respectively.

8.4 Stream Flow Changes

The results of this analysis are presented schematically in Figures 8-1 through 8-4 for existing conditions and Figures 8-5 through 8-8 for predicted future conditions. Each figure contains three schematics: one showing the North Nashua River, the second showing the Squannacook River, and the third showing the main stem of the Nashua River. Figure 8-1 shows the river flows for existing 7Q10 conditions, Figure 8-2 shows the river flows for average annual conditions, Figure 8-3 shows the river flows for average August conditions, and Figure 8-4 shows the average winter flows in the

Table 8-3
Average Annual Virgin, Existing (2000), and Future (2020) Flows

	Virgin Average Annual Flow (MGD)	Existing (2000) Subbasin Water Balance (MGD)	Existing (2000) Average Annual Flow (MGD)	Future (2020) Subbasin Water Balance (MGD)	Future (2020) Average Annual Flow (MGD)
Wachusett Watershed					
Quinapoxet River 2	20.297	(0.825)	19.472	(1.069)	19.228
Worcester Withdrawal[1]	-	(9.215)	-	(9.573)	-
Quinapoxet River 1	41.782	(0.561)	41.222	(1.044)	40.738
Stillwater River	44.080	(0.008)	44.072	(0.226)	43.854
Wachusett Reservoir	26.304	(2.019)	24.285	(2.869)	23.435
MWRA Withdrawal from Wachusett[2]	**-**	**(148.000)**	**-**	**(148.000)**	**-**
Wachusett Total	**132.464**	**(160.627)**	**129.051**	**(162.781)**	**127.255**
North Nashua River Watershed					
Phillips Brook	21.478	(0.893)	20.585	(0.885)	20.593
Whitman River[3]	38.627	(0.970)	37.657	(1.456)	37.171
Flag Brook[3]	17.163	(4.060)	13.103	(4.460)	12.704
North Nashua River 3	9.187	(1.318)	7.869	(0.357)	8.830
Monoosnoc Brook[3]	3.558	(3.418)	0.140	(4.380)	(0.823)
Falulah Brook[3]	5.018	(0.319)	4.699	(0.355)	4.662
North Nashua River 2	2.954	13.441	16.395	14.921	17.875
Fall Brook[3]	2.248	(0.937)	1.311	(1.196)	1.051
Wekepeke Brook[3]	6.606	(0.185)	6.421	(0.207)	6.399
North Nashua River 1	7.213	(0.262)	6.950	(0.324)	6.889
North Nashua River Total	**114.052**	**1.078**	**115.130**	**1.300**	**115.352**
Squannacook River Watershed					
Squannacook River 3	23.225	0.060	23.285	0.062	23.287
Squannacook River 2	38.256	(0.194)	38.062	(0.299)	37.957
Squannacook River 1	22.558	0.179	22.737	0.336	22.894
Mulpus Brook[3]	9.094	(0.384)	8.710	(0.367)	8.728
Squannacook River Total	**93.134**	**(0.340)**	**92.794**	**(0.268)**	**92.866**
Nissitissit River Watershed					
Nissitissit River	70.089	(0.061)	70.028	(0.077)	70.011
Nissitissit River Total	**70.089**	**(0.061)**	**70.028**	**(0.077)**	**70.011**
Nashua River Main Stem					
Nashua River Main Stem 4	7.241	2.296	9.537	2.555	9.796
Nashua River Main Stem 3	10.198	(0.094)	10.105	(0.107)	10.091
Bowers Brook	10.770	0.948	11.718	1.681	12.452
Catacunemaug Brook3	11.445	(0.292)	11.153	(0.454)	10.991
James Brook	2.231	(0.011)	2.220	(0.018)	2.212
Nashua River Main Stem 2	15.552	0.551	16.103	0.852	16.404
Unkety Brook	3.924	0.046	3.969	0.073	3.997
Nashua River Main Stem 1	15.071	0.008	15.079	0.013	15.084
	76.433	**3.452**	**79.885**	**4.594**	**81.027**
NASHUA W/OUT MWRA AND WORCESTER	**486.171**	**0.717**	**486.888**	**0.340**	**486.510**
NASHUA TOTAL	**486.171**	**(156.497)**	**486.888**	**(157.233)**	**486.510**

[1] Worcester Withdraws Water from the downstream end of the Quinapoxet 2 Subarea

[2] MWRA Withdraws water from the Downstream end of the Wachusett Watershed

[3] Subarea has use of multi-month reservoirs, thereby requiring more detailed analysis to make conclusions for 7Q10 or August yields. Average annual yield is reliable for these subbasins.

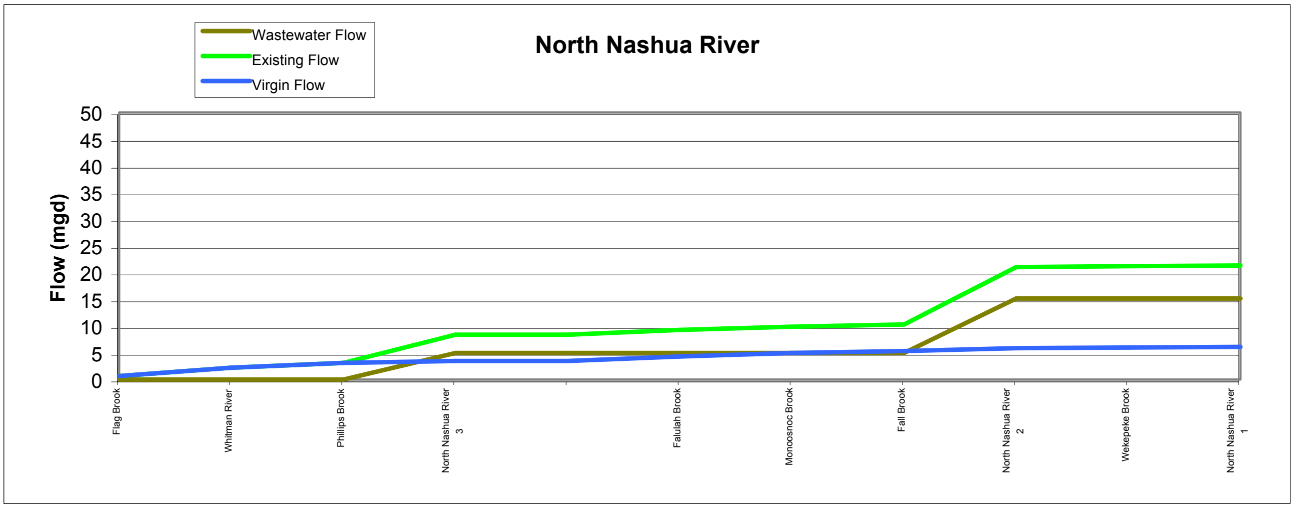
Table 8-4
Average Winter Virgin, Existing (2000), and Future (2020) Flows

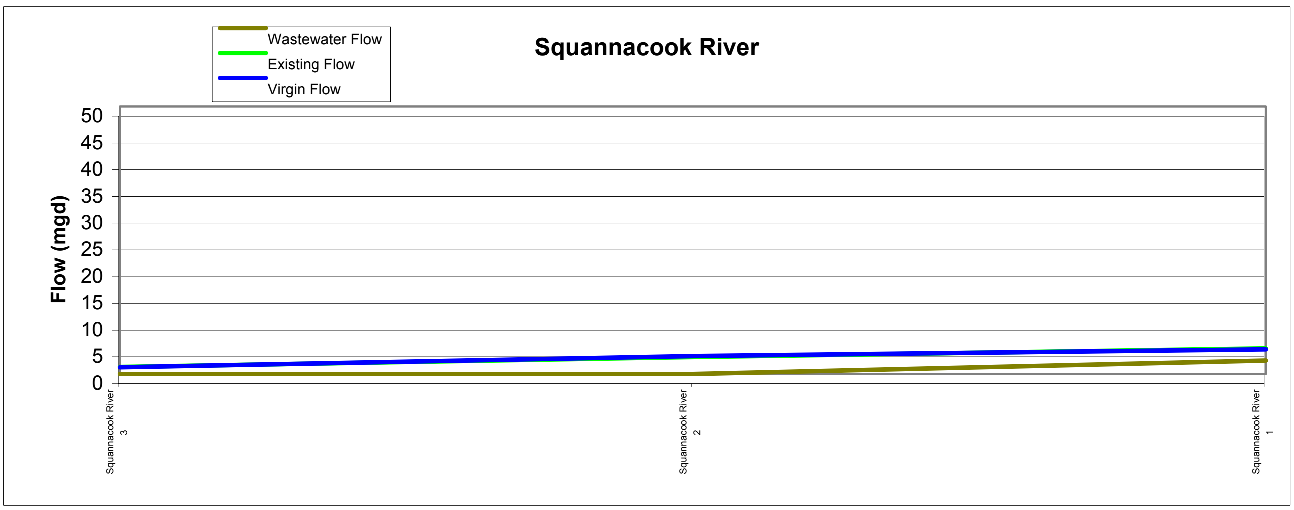
	Virgin Winter Flow (MGD)	Existing (2000) Subbasin Water Balance (MGD)	Existing (2000) Winter Flow (MGD)	Future (2020) Subbasin Water Balance (MGD)	Future (2020) Winter Flow (MGD)
Wachusett Watershed					
Quinapoxet River 2	32.280	(0.627)	31.653	(0.996)	31.285
Worcester Withdrawal[1]	-	(7.740)	-	(8.041)	-
Quinapoxet River 1	66.450	(0.711)	65.739	(1.372)	65.078
Stillwater River	70.104	0.003	70.107	(0.203)	69.902
Wachusett Reservoir	41.834	(2.014)	39.820	(2.916)	38.918
MWRA Withdrawal from Wachusett[2]	**-**	**(148.000)**	**-**	**(148.000)**	**-**
Wachusett Total	**210.670**	**(159.090)**	**207.320**	**(161.528)**	**205.183**
North Nashua River Watershed					
Phillips Brook	24.916	(1.067)	23.849	(1.057)	23.859
Whitman River[3]	44.811	(1.027)	43.784	(1.536)	43.274
Flag Brook[3]	19.911	(3.980)	15.930	(4.384)	15.526
North Nashua River 3	10.658	(2.472)	8.186	(1.469)	9.189
Monoosnoc Brook[3]	3.188	(3.547)	(0.359)	(4.526)	(1.338)
Falulah Brook[3]	4.496	(0.469)	4.027	(0.533)	3.963
North Nashua River 2	2.647	14.569	17.216	16.062	18.709
Fall Brook[3]	2.014	(1.082)	0.932	(1.383)	0.632
Wekepeke Brook[3]	7.105	0.067	7.172	0.112	7.217
North Nashua River 1	7.757	(0.328)	7.428	(0.406)	7.351
North Nashua River Total	**127.502**	**0.663**	**128.165**	**0.880**	**128.382**
Squannacook River Watershed					
Squannacook River 3	25.982	0.052	26.034	0.054	26.036
Squannacook River 2	42.798	(0.185)	42.613	(0.286)	42.512
Squannacook River 1	25.236	0.221	25.458	0.370	25.606
Mulpus Brook[3]	9.780	(0.357)	9.424	(0.338)	9.443
Squannacook River Total	**103.796**	**(0.268)**	**103.529**	**(0.200)**	**103.597**
Nissitissit River Watershed					
Nissitissit River	78.409	(0.096)	78.313	(0.134)	78.275
Nissitissit River Total	**78.409**	**(0.096)**	**78.313**	**(0.134)**	**78.275**
Nashua River Main Stem					
Nashua River Main Stem 4	7.787	2.291	10.079	2.553	10.341
Nashua River Main Stem 3	10.968	(0.140)	10.828	(0.156)	10.812
Bowers Brook	11.583	0.918	12.500	1.621	13.203
Catacunemaug Brook3	12.308	(0.349)	11.960	(0.531)	11.778
James Brook	2.399	(0.018)	2.381	(0.031)	2.368
Nashua River Main Stem 2	16.725	0.724	17.449	1.021	17.746
Unkety Brook	4.220	0.037	4.257	0.059	4.279
Nashua River Main Stem 1	16.208	0.007	16.215	0.012	16.220
	82.198	**3.471**	**85.668**	**4.548**	**86.746**
NASHUA W/OUT MWRA AND WORCESTER	**602.575**	**0.421**	**602.996**	**(0.393)**	**602.182**
NASHUA TOTAL	**602.575**	**(155.320)**	**602.996**	**(156.434)**	**602.182**

[1] Worcester Withdraws Water from the downstream end of the Quinapoxet 2 Subarea

[2] MWRA Withdraws water from the Downstream end of the Wachusett Watershed

[3] Subarea has use of multi-month reservoirs, thereby requiring more detailed analysis to make conclusions for 7Q10 or August yields. Average annual yield is reliable for these subbasins.





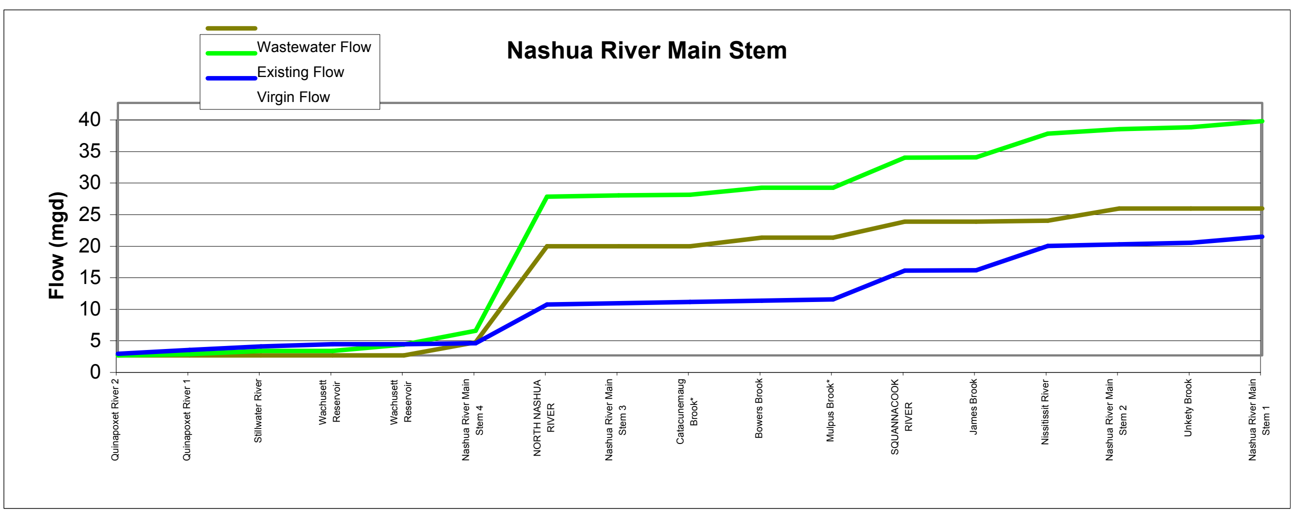
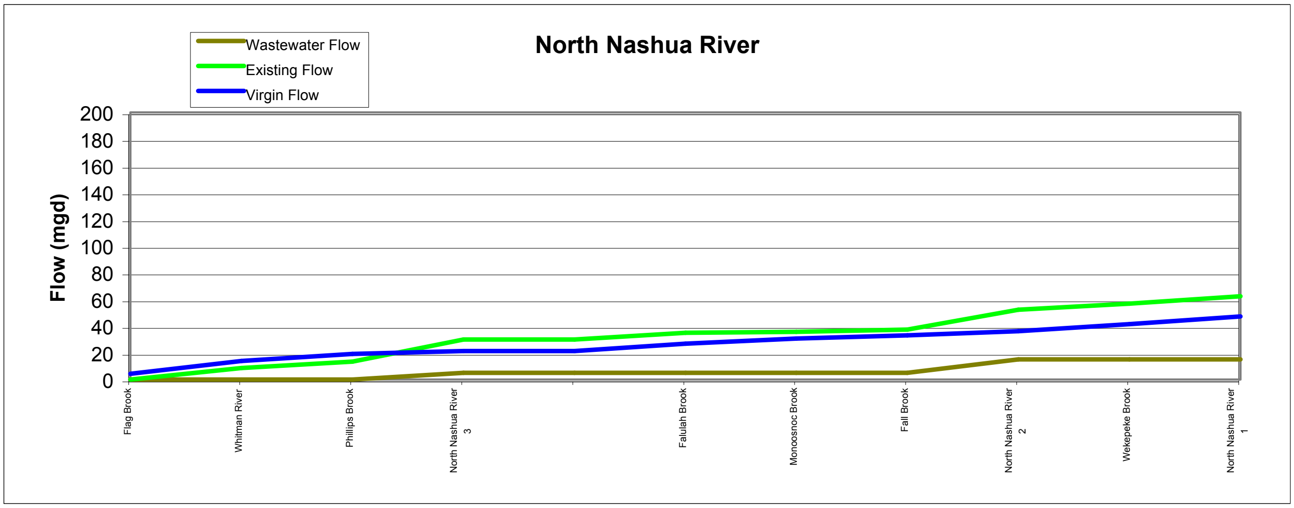
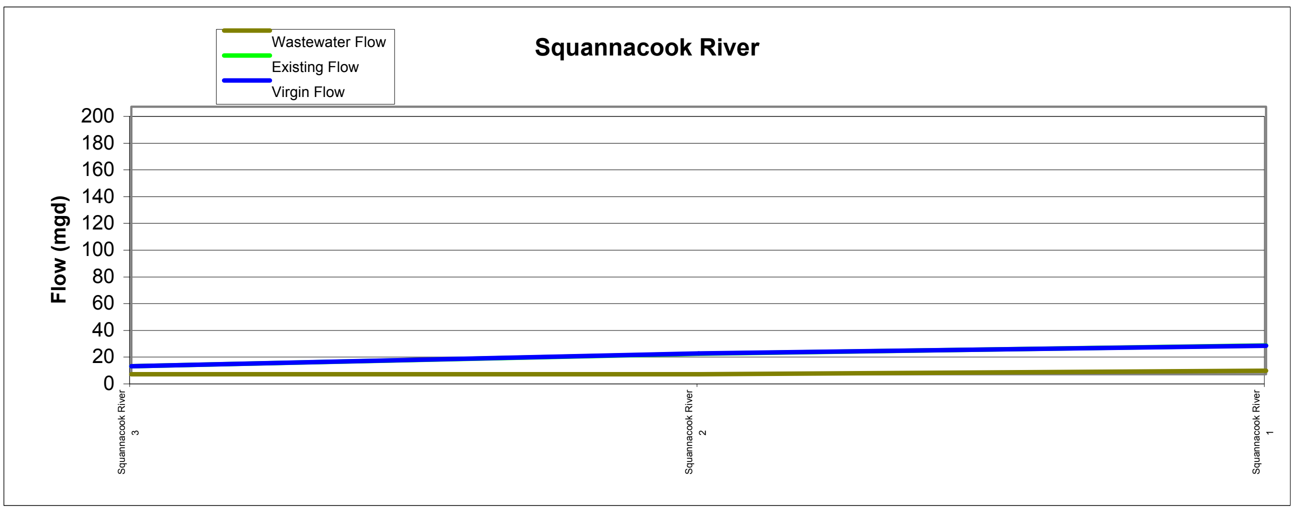


Figure 8-1
Existing (2000) Nashua River 7Q10 Flows





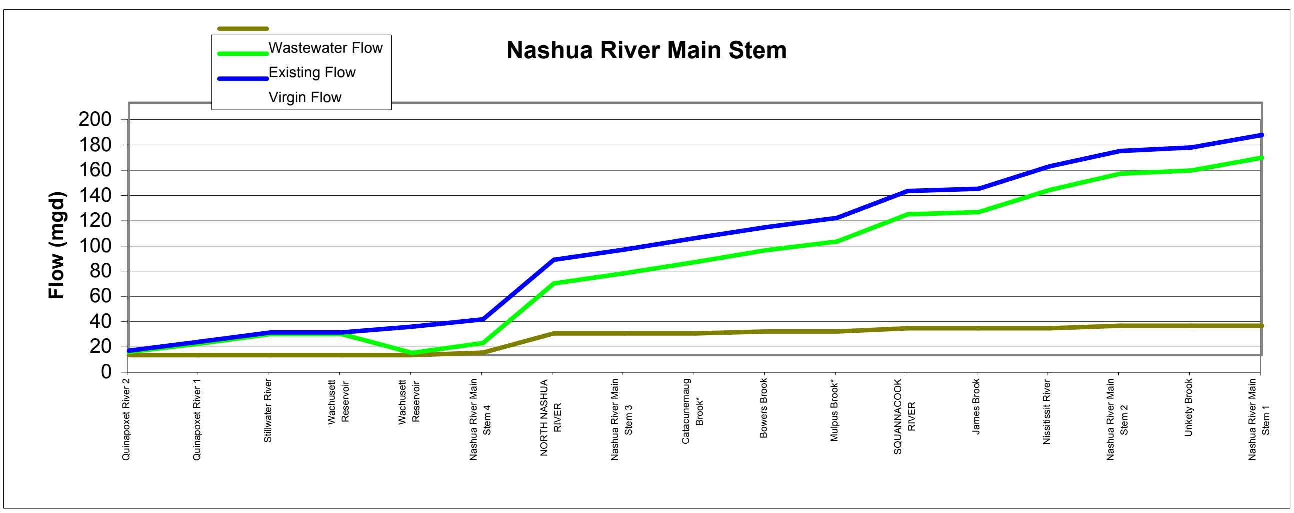
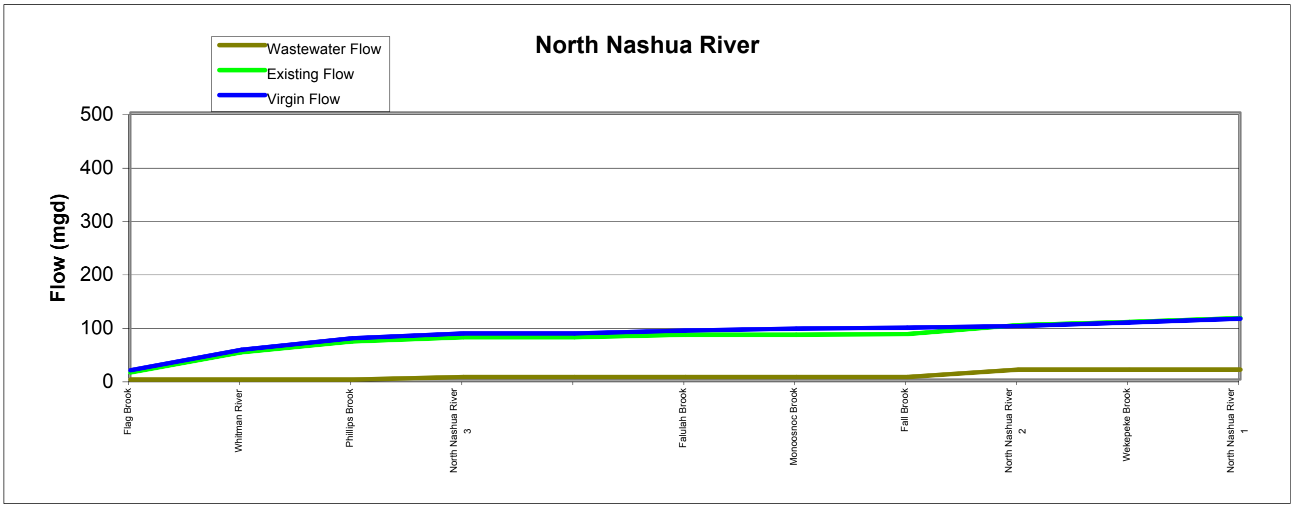
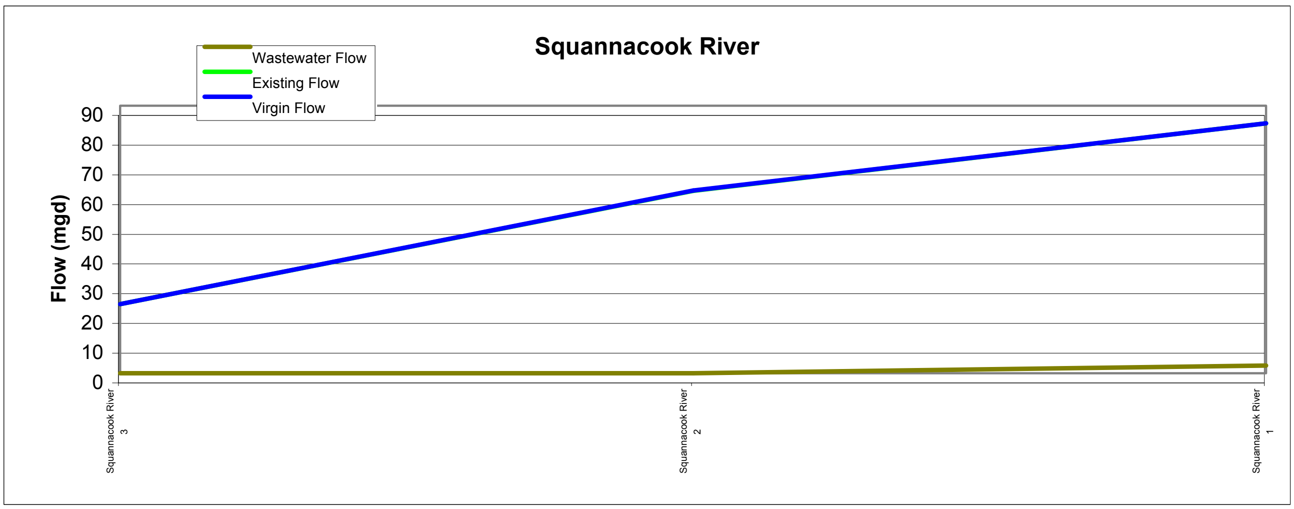


Figure 8-2
Existing (2000) Nashua River Average August Flows





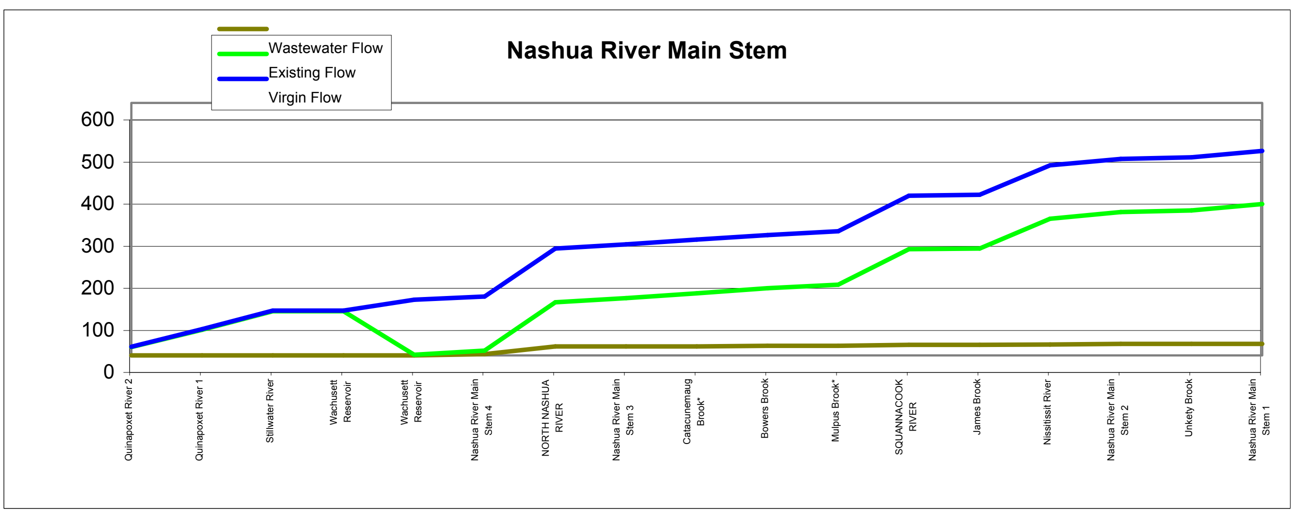
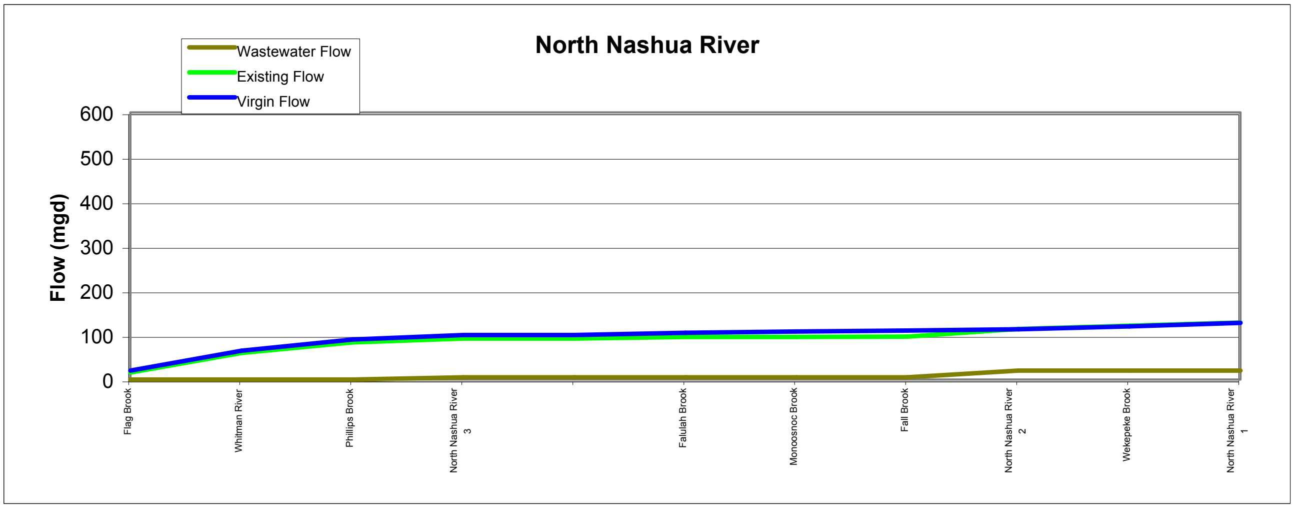
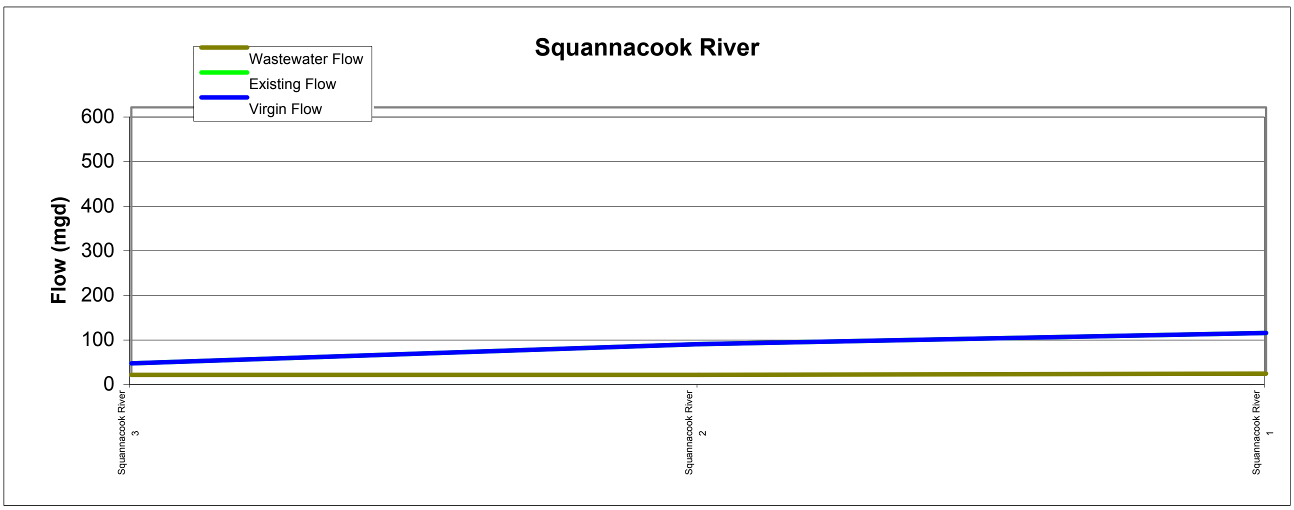


Figure 8-3
Existing (2000) Nashua River Average Annual Flows





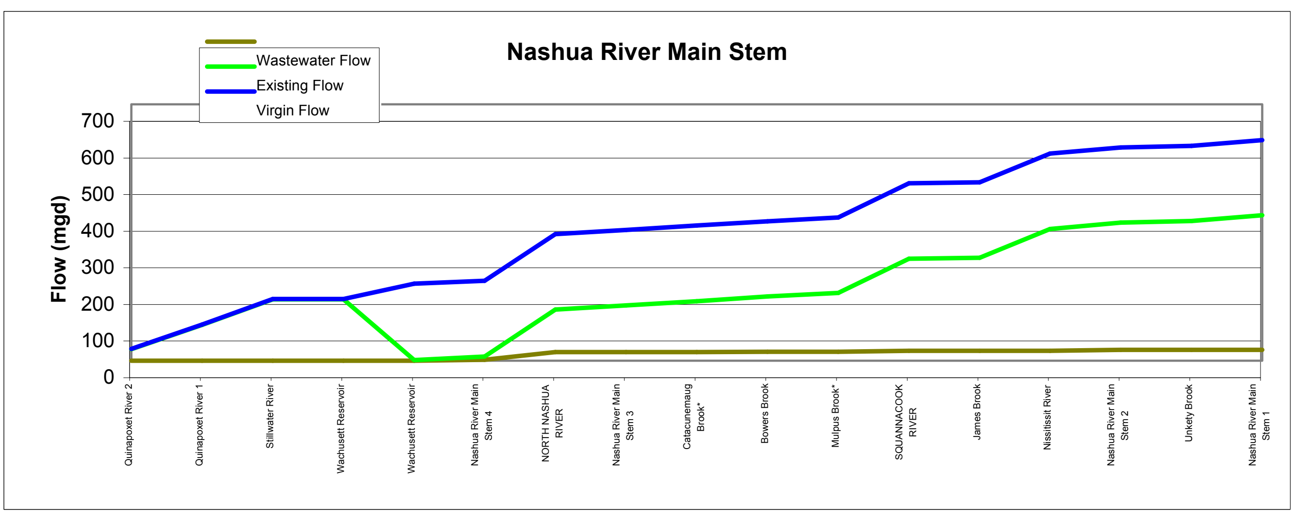


Figure 8-4
Existing (2000) Nashua River Average Winter Flows

river. Figures 8-5 through 8-8 show the river flows under predicted future (2020) conditions for each of the four scenarios, in the same order as the existing conditions.

7Q10 and August flows show the most stress. There is a large impact in flow volumes in some subreaches of the major branches, where subarea flows are diverted to downstream wastewater treatment plants. In the North Nashua River, in particular, flow is diverted a substantial distance downstream from Flag Brook, Whitman River, and Phillips Brook to the Fitchburg West Wastewater Treatment Plant and from Falulah Brook and Monoosnoc Brook to the Fitchburg East and Leominster Wastewater Treatment Plants. The reduction in streamflow is unknown upstream of either of the treatment plants because the marginal contributions of upstream subareas are zero, according to this analysis, which is not adequate because of the presence of numerous multi-month reservoirs.

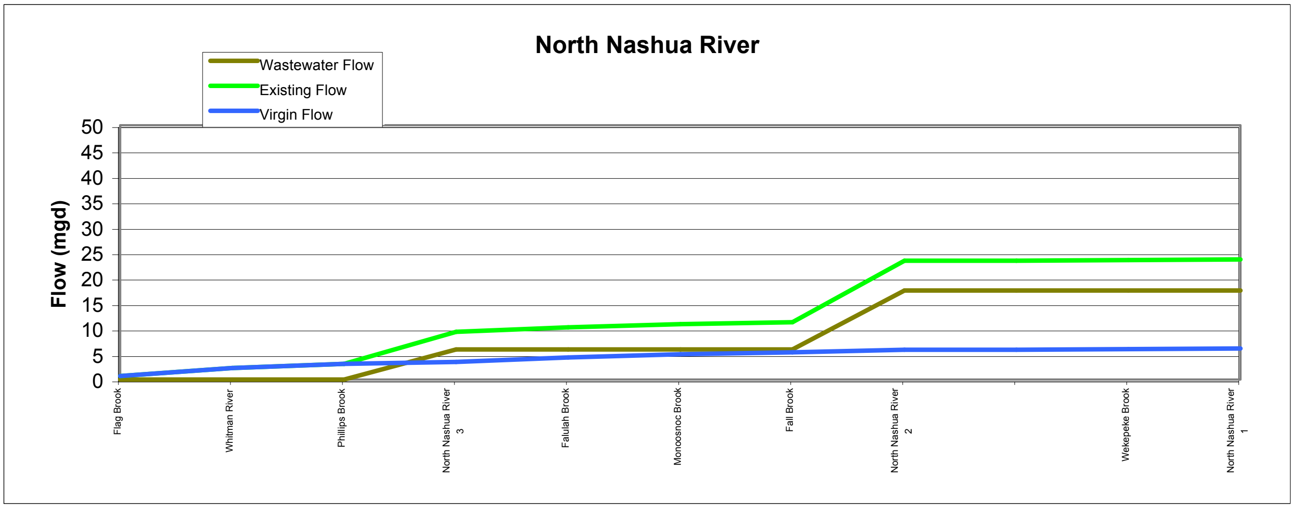
In the North Nashua River and the Main Stem of the Nashua River—the two branches with wastewater discharges—the percentage of flow that is wastewater becomes quite significant in low flow conditions (August flows and particularly 7Q10 flows). At the downstream end of the North Nashua River, wastewater flow (15.5 mgd) accounts for more than 73% of the total existing flow (21.2 mgd) during 7Q10 conditions. At the downstream end of the Nashua River, this percent declines to slightly greater than 41%--21.9 mgd of wastewater flow in a total of 52.9 mgd existing 7Q10 flow. During these 7Q10 conditions, the combination of the use of multi-month reservoirs and the probable drawdown of groundwater supplies, the existing flow is substantially greater than the estimated virgin flow at the downstream end of the North Nashua River, where the virgin flow was calculated to be 6.3 mgd, as well as at the downstream end of the Main Stem of the Nashua River, where the virgin flow was calculated to be 17.3 mgd.

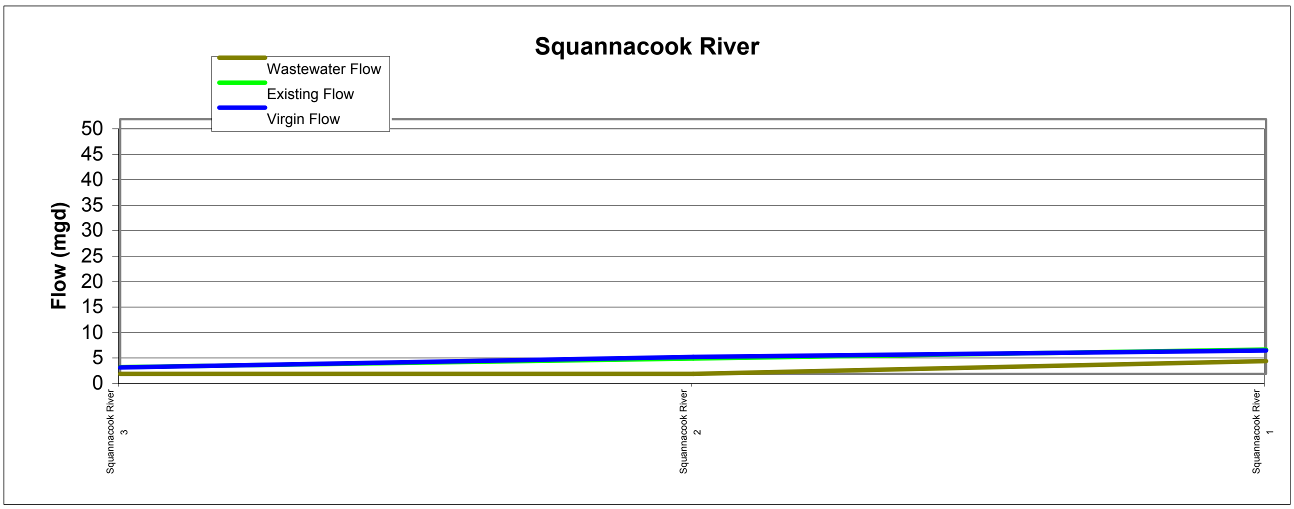
Average annual and winter flows are not affected significantly. This is immediately apparent in the figures, where the non-wastewater portion of the flows clearly accounts for the majority of the flow during higher flows, and it is at least 80% of the virgin flow.

The impacts present in existing conditions (2000) become much more pronounced in the future (2020) scenario. In the North Nashua River, the percent of the flow that is wastewater in 7Q10 conditions increases from 73% to 91%, and the percent wastewater in the Main Stem increases from 41% to 47%.

8.5 Flow Stressed Systems

After compiling data for the average August and 7Q10 flows, existing and predicted flows were compared with estimated virgin flows in order to approximate the level of stress of each subbasin. DEM guidelines, as described in the draft memorandum: *Stressed Basins in Massachusetts* (Office of Water Resources, February 26, 2001), were followed to estimate the stress level of each subbasin.





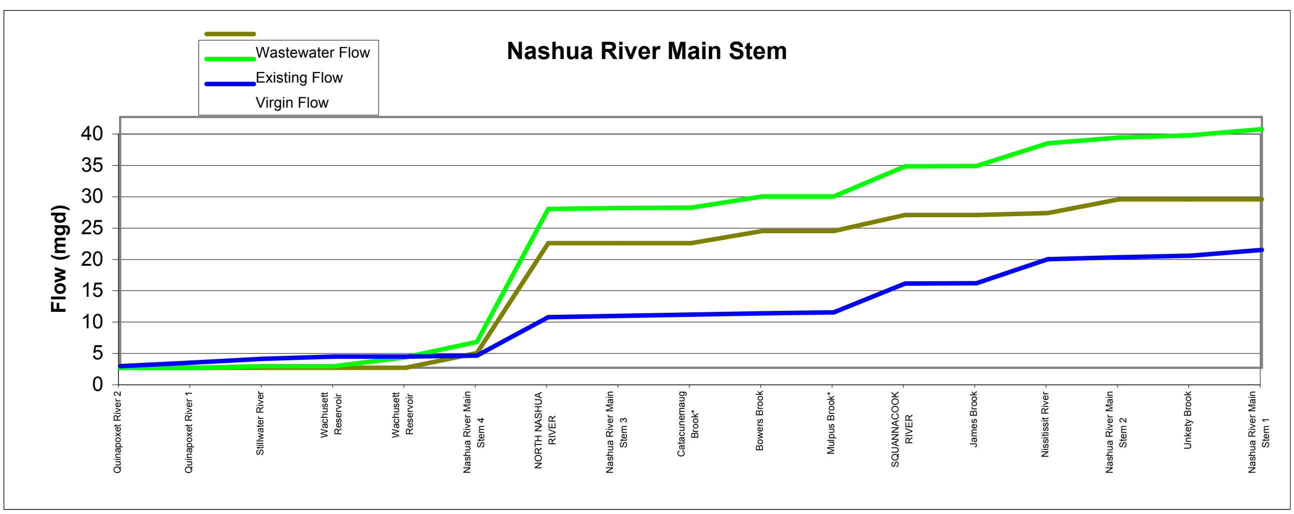
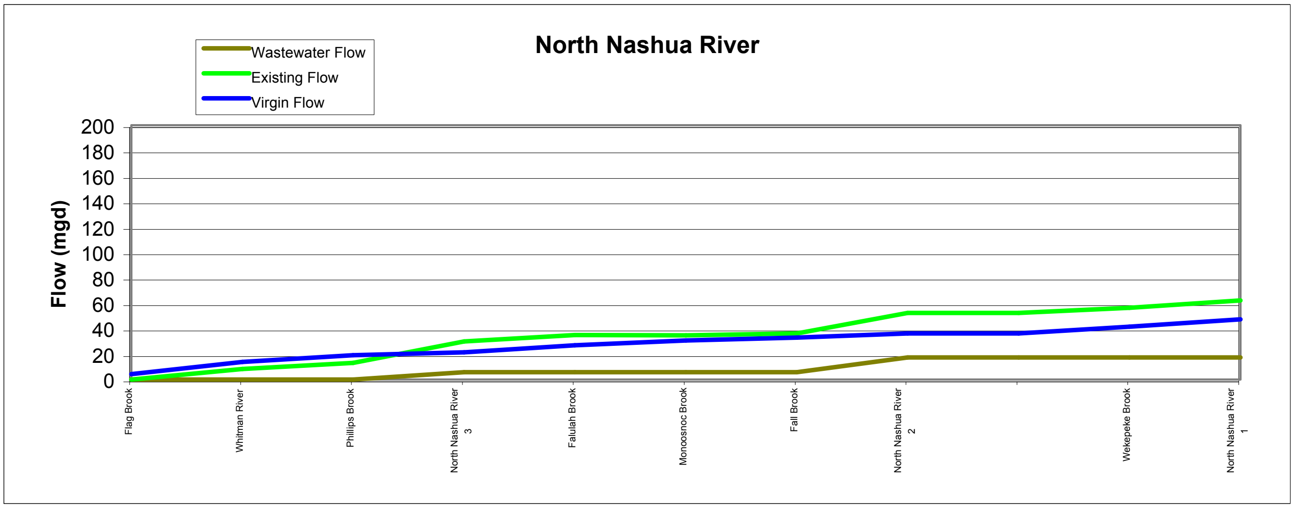
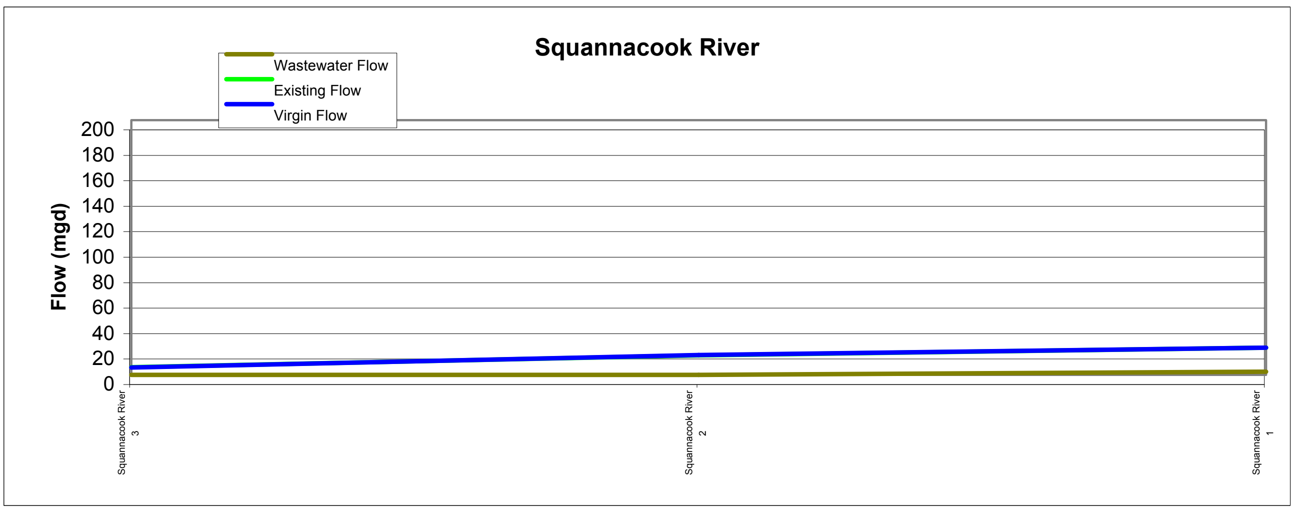


Figure 8-5
Future (2020) Nashua River 7Q10 Flows





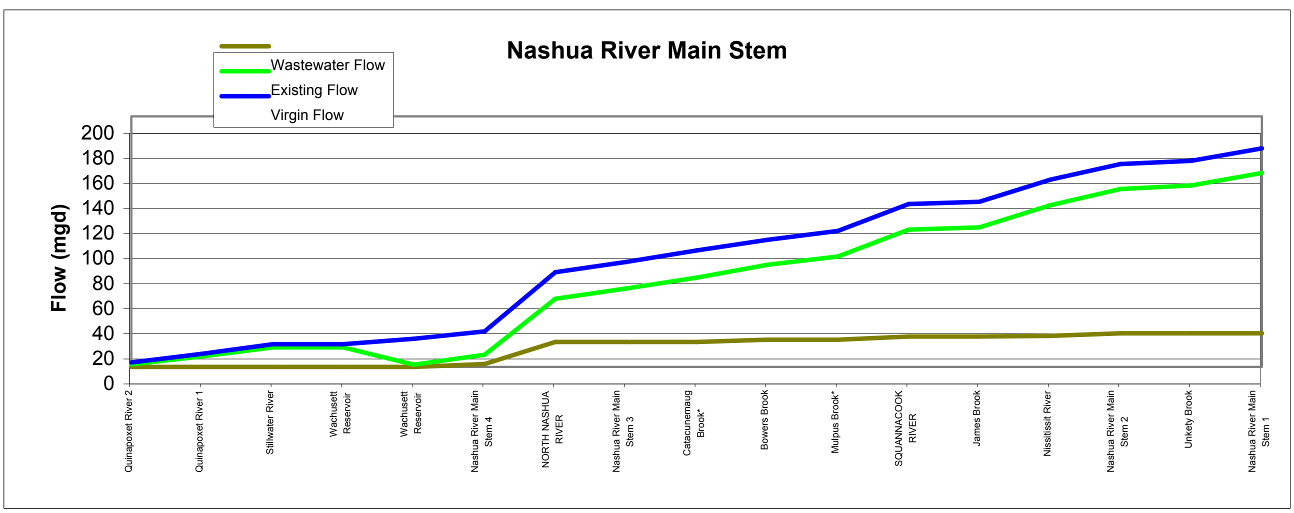
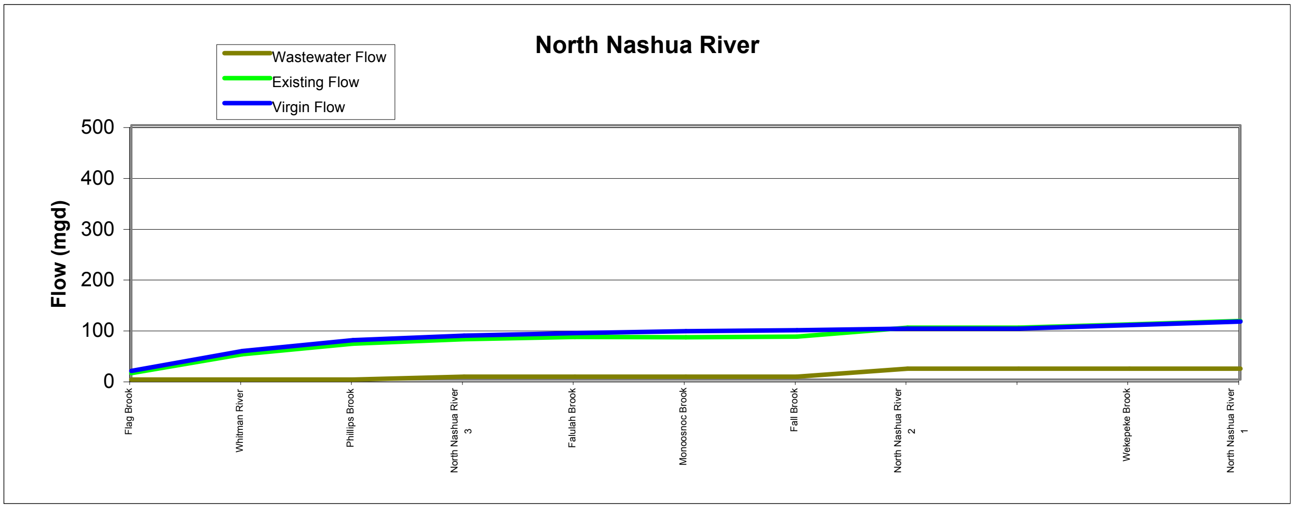
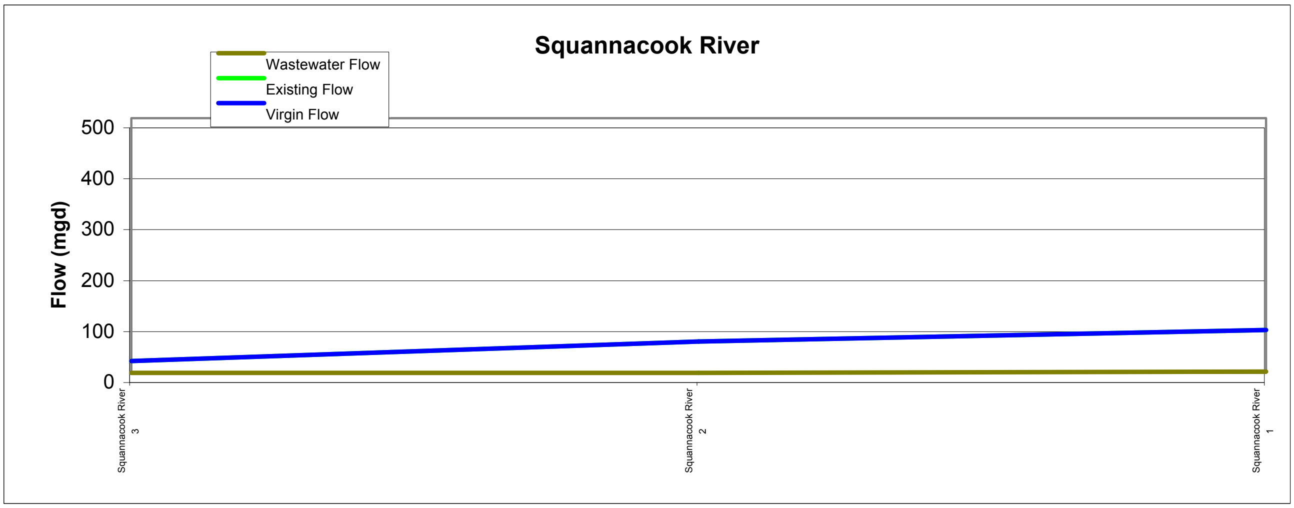


Figure 8-6
Future (2020) Nashua River Average August Flows





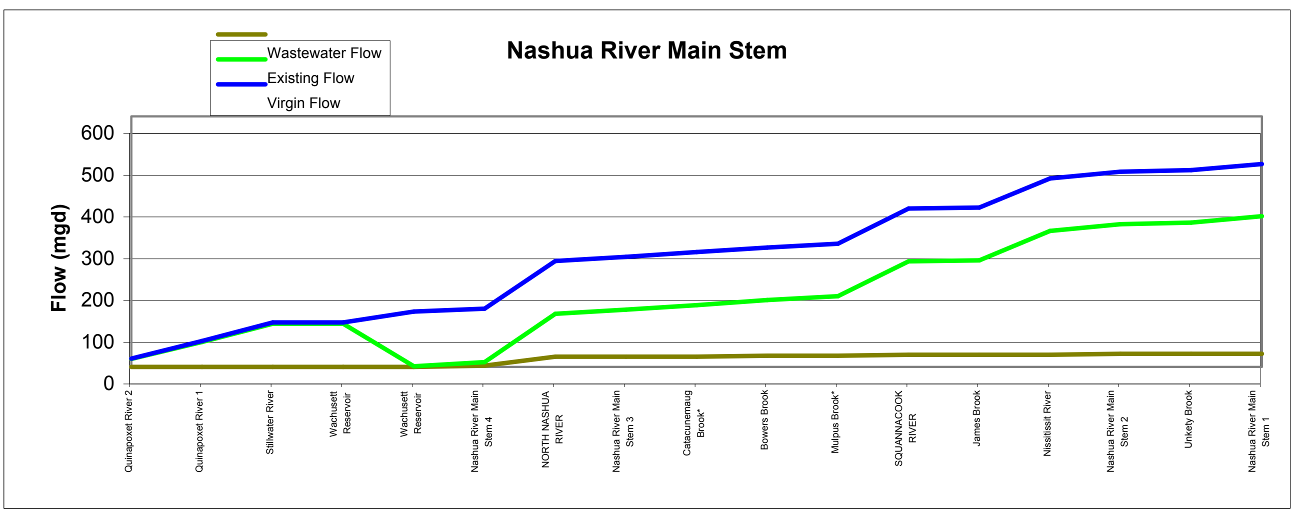
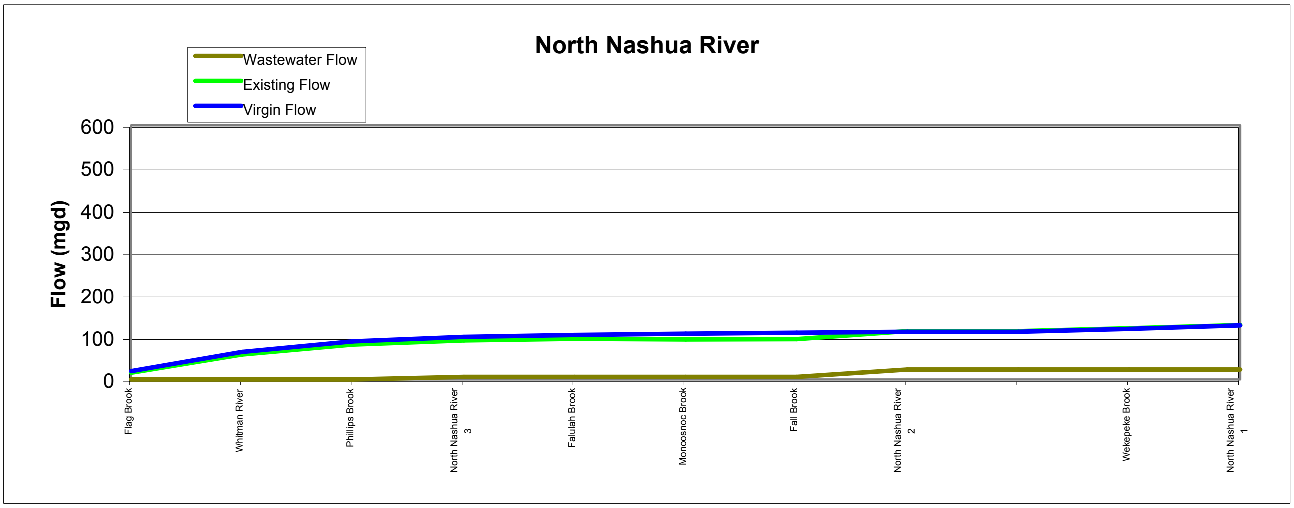
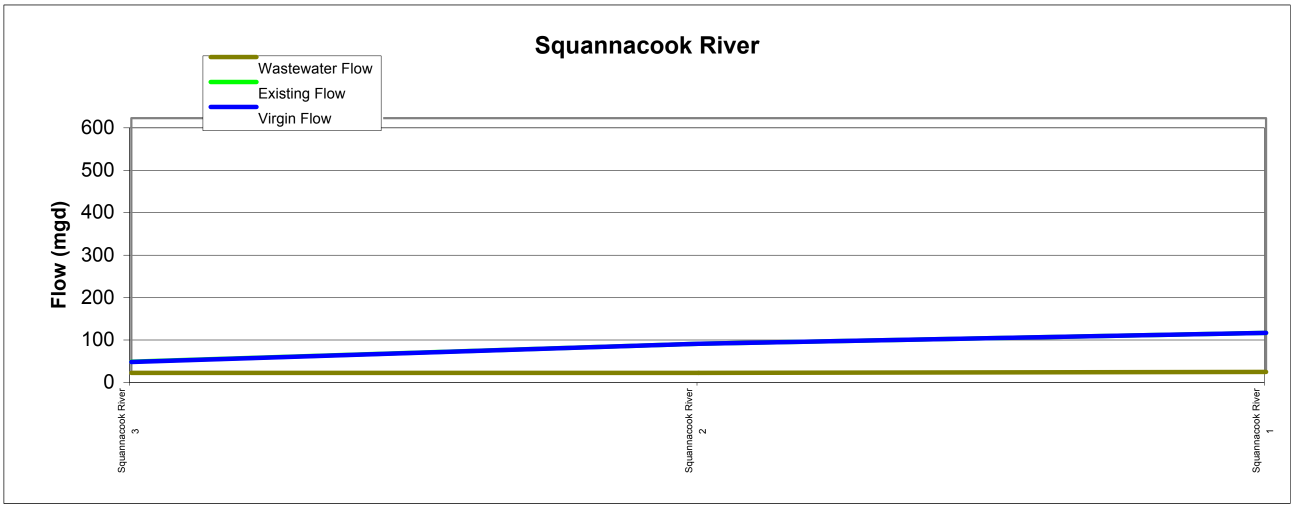


Figure 8-7
Future (2020) Nashua River Average Annual Flows





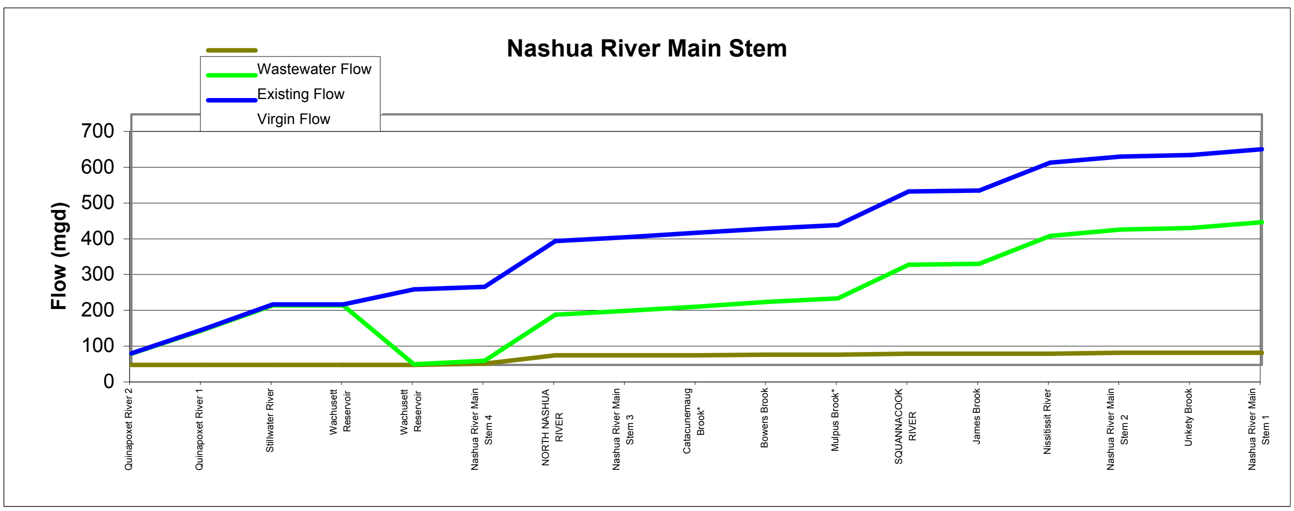


Figure 8-8
Future (2020) Nashua River Average Winter Flows

The DEM has defined three hydrologic stress classifications:

- High-Stress: net average August outflow equals or exceeds estimated natural August average flow

- Medium-Stress: net 7Q10 outflow equals or exceeds estimated natural 7Q10 flow

- Low-Stress: no net loss to the sub-basin on an average annual basin

Based on these classifications, the stress levels for each subarea were determined for existing conditions as well as predicted conditions in the year 2020. The stress level of each subarea is presented in Table 8-5 for existing conditions and Table 8-6 for future conditions.

Following the DEM stress classification system,

- One subarea—Flag Brook—is predicted to be high-stressed (net withdrawals exceeding median August flow) in the Nashua River Basin under both existing (2000) and future (2020) conditions. Additionally, Monoosnoc Brook is predicted to be highly stressed in the future.

- Seven subareas are predicted to have medium-stress under existing conditions (net 7Q10 outflow equal/exceeding natural 7Q10): Quinapoxet River 2, Wachusett Reservoir, Monoosnoc Brook, Falulah Brook, Fall Brook, Wekepeke Brook, and Mulpus Brook. In the future, Quinapoxet River 1 and Catacunemaug Brook are expected to be added to the medium-stress list.

It is important to note that most of the basins that are predicted to have some form of stress also contain multi-month reservoirs. These reservoirs are capable of storing large flows in the spring and holding them for use during low flow periods in late summer. Because of the stored flow, the impact of large demands in these basins may not be as great as the stress-classification system implies; it is possible that normal low flows are still being released from these reservoirs. To properly determine the stress levels in these basins, a more detailed study of the reservoirs and their releases is required.

Because the Wachusett watershed is highly managed for the Worcester and MWRA withdrawals, these withdrawals were not considered in the evaluation of stress in the Wachusett Watershed—a much more detailed analysis would be required to evaluate their uses. Instead, the calculations were based on other uses of water in the watershed, particularly withdrawals by Holden, Rutland, Princeton, Sterling, and West Boylston. Based on these withdrawals, two of the four subareas in the Wachusett Watershed were calculated to have medium-stress under existing (2000) conditions, and three of the four subareas were calculated to have medium stress under future (2020) conditions.

Table 8-5
Existing (2000) Stress Level in Nashua River Subareas

	7Q10 Virgin Flow (MGD)	August Existing (2000) Subbasin Inflow/Outflow (MGD)	7Q10 Existing (2000) Flow[1] (MGD)	Average August Virgin Flow (MGD)	August Existing (2000) Subbasin Inflow/Outflow (MGD)	August Existing (2000) Flow (MGD)	Stress Level
Wachusett Watershed							
Quinapoxet River 2	0.275	(0.993)	(0.718)	3.460	(0.993)	2.467	Medium-Stress
Quinapoxet River 1	0.567	(0.379)	0.188	7.123	(0.379)	6.744	Low-Stress
Stillwater River	0.598	(0.083)	0.515	7.515	(0.083)	7.432	Low-Stress
Wachusett Reservoir	0.357	(2.181)	(1.824)	4.485	(2.181)	2.304	Medium-Stress
North Nashua River Watershed							
Phillips Brook	0.862	(0.551)	0.311	5.324	(0.551)	4.773	Low-Stress
Whitman River*	1.550	(0.833)	0.717	9.575	(0.833)	8.742	Low-Stress
Flag Brook*	0.689	(4.624)	(3.935)	4.255	(4.624)	(0.369)	High-Stress
North Nashua River 3	0.369	0.645	1.013	2.277	0.645	2.922	Low-Stress
Monoosnoc Brook*	0.622	(3.140)	(2.519)	3.840	(3.140)	0.699	Medium-Stress
Falulah Brook*	0.877	(0.431)	0.446	5.415	(0.431)	4.985	Low-Stress
North Nashua River 2	0.516	10.247	10.763	3.188	10.247	13.435	Low-Stress
Fall Brook*	0.393	(0.670)	(0.277)	2.426	(0.670)	1.756	Medium-Stress
Wekepeke Brook*	0.125	(0.838)	(0.712)	5.254	(0.838)	4.416	Medium-Stress
North Nashua River 1	0.137	(0.102)	0.035	5.736	(0.102)	5.634	Low-Stress
Squannacook River Watershed							
Squannacook River 3	1.267	0.059	1.327	5.880	0.059	5.940	Low-Stress
Squannacook River 2	2.088	(0.271)	1.816	9.686	(0.271)	9.415	Low-Stress
Squannacook River 1	1.231	0.438	1.669	5.711	0.438	6.149	Low-Stress
Mulpus Brook*	0.173	(0.568)	(0.396)	7.233	(0.568)	6.665	Medium-Stress
Nissitissit River Watershed							
Nissitissit River	3.825	(0.108)	3.717	17.745	(0.108)	17.637	Low-Stress
Nashua River Main Stem							
Nashua River Main Stem 4	0.138	2.080	2.217	5.759	2.080	7.839	Low-Stress
Nashua River Main Stem 3	0.194	(0.017)	0.177	8.111	(0.017)	8.094	Low-Stress
Bowers Brook	0.205	0.889	1.094	8.566	0.889	9.456	Low-Stress
Catacunemaug Brook*	0.217	(0.099)	0.119	9.103	(0.099)	9.004	Low-Stress
James Brook	0.042	(0.003)	0.039	1.774	(0.003)	1.771	Low-Stress
Nashua River Main Stem 2	0.295	0.417	0.712	12.369	0.417	12.786	Low-Stress
Unkety Brook	0.251	0.055	0.306	2.613	0.055	2.668	Low-Stress
Nashua River Main Stem 1	0.963	0.009	0.972	10.038	0.009	10.047	Low-Stress

* Subarea has use of multi-month reservoirs, thereby requiring more detailed analysis to make conclusions for 7Q10 or August yields. Average annual yield is reliable for these subbasins.
[1] 7Q10 Existing Flow = 7Q10 Virgin Flow + August 2000 Inflow/Outflow
High Stress Subareas are highlighted red
Medium Stress Subareas are highlighted orange
Low Stress Subareas are not highlighted

Table 8-6
Predicted Future (2020) Stress Level in Nashua River Subareas

	7Q10 Virgin Flow (MGD)	August Future (2020) Subbasin Inflow/Outflow (MGD)	7Q10 Future (2020) Flow[1] (MGD)	Average August Virgin Flow (MGD)	August Future(2020) Subbasin Inflow/Outflow (MGD)	August Future (2020) Flow (MGD)	Stress Level
Wachusett Watershed							
Quinapoxet River 2	0.275	(1.383)	(1.107)	3.460	(1.383)	2.078	Medium-Stress
Quinapoxet River 1	0.567	(0.893)	(0.326)	7.123	(0.893)	6.230	Medium-Stress
Stillwater River	0.598	(0.322)	0.276	7.515	(0.322)	7.193	Low-Stress
Wachusett Reservoir	0.357	(2.864)	(2.507)	4.485	(2.864)	1.621	Medium-Stress
North Nashua River Watershed							
Phillips Brook	0.862	(0.546)	0.316	5.324	(0.546)	4.778	Low-Stress
Whitman River*	1.550	(1.349)	0.201	9.575	(1.349)	8.226	Low-Stress
Flag Brook*	0.689	(5.072)	(4.383)	4.255	(5.072)	(0.818)	High-Stress
North Nashua River 3	0.369	1.642	2.010	2.277	1.642	3.919	Low-Stress
Monoosnoc Brook*	0.622	(4.034)	(3.413)	3.840	(4.034)	(0.194)	High-Stress
Falulah Brook*	0.877	(0.432)	0.444	5.415	(0.432)	4.983	Low-Stress
North Nashua River 2	0.516	11.523	12.039	3.188	11.523	14.712	Low-Stress
Fall Brook*	0.393	(0.853)	(0.460)	2.426	(0.853)	1.573	Medium-Stress
Wekepeke Brook*	0.125	(1.043)	(0.918)	5.254	(1.043)	4.211	Medium-Stress
North Nashua River 1	0.137	(0.125)	0.012	5.736	(0.125)	5.611	Low-Stress
Squannacook River Watershed							
Squannacook River 3	1.267	0.062	1.329	5.880	0.062	5.942	Low-Stress
Squannacook River 2	2.088	(0.419)	1.668	9.686	(0.419)	9.267	Low-Stress
Squannacook River 1	1.231	0.554	1.785	5.711	0.554	6.265	Low-Stress
Mulpus Brook*	0.173	(0.587)	(0.414)	7.233	(0.587)	6.646	Medium-Stress
Nissitissit River Watershed							
Nissitissit River	3.825	(0.154)	3.671	17.745	(0.154)	17.591	Low-Stress
Nashua River Main Stem							
Nashua River Main Stem 4	0.138	2.292	2.429	5.759	2.292	8.051	Low-Stress
Nashua River Main Stem 3	0.194	(0.024)	0.169	8.111	(0.024)	8.087	Low-Stress
Bowers Brook	0.205	1.610	1.815	8.566	1.610	10.176	Low-Stress
Catacunemaug Brook*	0.217	(0.199)	0.018	9.103	(0.199)	8.903	Low-Stress
James Brook	0.042	(0.005)	0.037	1.774	(0.005)	1.769	Low-Stress
Nashua River Main Stem 2	0.295	0.622	0.917	12.369	0.622	12.991	Low-Stress
Unkety Brook	0.251	0.087	0.338	2.613	0.087	2.701	Low-Stress
Nashua River Main Stem 1	0.963	0.014	0.977	10.038	0.014	10.052	Low-Stress

* Subarea has use of multi-month reservoirs, thereby requiring more detailed analysis to make conclusions for 7Q10 or August yields. Average annual yield is reliable for these subbasins.

[1] 7Q10 Future Flow = 7Q10 Virgin Flow + August 2020 Inflow/Outflow

High Stress Subareas are highlighted red

Medium Stress Subareas are highlighted orange

Low Stress Subareas are not highlighted

The guidelines developed by DEM address water quantity only and employ only flow as an indicator of stress in a subarea or stream. Stress for aquatic life can also be from other factors, such as poor water quality or loss of habitat. Additionally, aquatic life may be severely impacted during extended periods of low flow whether or not the subarea is classified as stressed.

Section 9
Findings and Recommendations

9.1 General

Available water is a critical component for the future of the Nashua River watershed residents and for protection of aquatic resources. Despite being in a water-rich region, many rivers in Massachusetts are severely taxed. This report provides the foundation on which future water use decisions can be made in the Nashua River watershed. This study examines the impact of water withdrawal and distribution, and wastewater collection and discharge on the water resources in the watershed.

9.2 Water Supplies

The headwaters of the Nashua River contain Wachusett Reservoir, a major water supply for the metropolitan Boston area. In addition, the City of Worcester has several reservoirs in the headwaters of the Nashua River, which that city uses as water supply. Nineteen communities in the watershed withdraw water either from groundwater wells or from surface water reservoirs for public water supplies. Future growth in these communities will put greater demand on the water resources in the Nashua River.

The existing water supplies withdraw 183 mgd annually from the groundwater and surface waters in the watershed, or 25.7 mgd if Worcester's and MWRA's water supplies are excluded. The water need for communities with supplies in the watershed is forecasted to increase to 187 mgd in the year 2020 or 29.7 mgd if Worcester and MWRA water supplies are not included.

Currently, 23.8 mgd of water is distributed in water service areas annually by the public water suppliers. This amount is forecasted to increase to 28.3 mgd in the year 2020.

The assessment of water conservation by the public water suppliers found room for improvement. Two metrics, residential water use of 80 gpcd or less and unaccounted for water (UAW) of 15 percent or less, were used to evaluate the water conversation programs for each public water supplier. Five out of 25 water suppliers exceeded the residential benchmark of 80 gpcd. Eight water suppliers exceeded the UAW benchmark of 15%. In most cases, the water supplier explained the high UAW in the ASR. Additionally, seven public water suppliers reported UAW 5% or less, which is unlikely to be accurate.

An evaluation was performed to identify public water supplies that are in proximity to either a MCP site or solid waste facility. A ranking system was developed based on the proximity and the risk posed by the site to the water supply. Six community water supplies and three non-community water supplies were considered to be at risk from either a nearby MCP site or a solid waste facility.

9.3 Wastewater Discharges

Seventeen communities have wastewater collection systems in the watershed. A total of 25.0 mgd of wastewater is collected annually in the watershed. The amount of wastewater collected is forecasted to increase to 32.7 mgd in the year 2020. Currently, four communities export wastewater from the watershed: Ashburnham and Gardner (to Gardner's Wastewater Treatment Plant), and Holden and Rutland (to Worcester's Upper Blackstone wastewater treatment plant).

The Nashua River and its tributaries receive the discharge of wastewater from seven public wastewater treatment plants. Three wastewater treatment plants discharge to the North Nashua River. Wastewater treatment plants also discharge to the main stem of the Nashua River.

The North Nashua River is a good example of the impact of water withdrawal and wastewater discharge. The headwaters of the North Nashua River contain numerous water supply sources, both groundwater and surface water reservoirs. Water is withdrawn from these headwater sources and discharged downstream at the municipal-owned wastewater treatment plants of Fitchburg and Leominster.

9.4 Inflow/Outflow Analysis

An inflow/outflow analysis for the Nashua River was performed. The watershed was divided into 27 separate subareas, which were used to calculate the water balance at small scale. This process was performed to determine areas of the watershed that may be subject to diminished river flow, as well as areas that may have the potential for additional withdrawal. The 27 subareas have been grouped into five separate subwatersheds: the Wachusett, North Nashua River, Squannacook River, Nissitissit River, and main Nashua River.

The approach used in the inflow/outflow analysis was to tally the sources and uses of water in each subarea. Information and location of water supply withdrawals, water distribution and wastewater collection service areas, and wastewater discharge was collected. Annual, August, and winter demand periods were evaluated.

Annual 2000

- The 2000 annual inflow/outflow analysis shows a net gain of 0.7 mgd for the Nashua River watershed or a net loss of 156.5 mgd when MWRA's and Worcester's water withdrawals are included.

- Excluding Worcester's and MWRA's large water withdrawals, the net gain of water in the watershed is from the difference in water withdrawn (26.3 mgd) to water distributed (24.4 mgd), a loss of 1.9 mgd from the watershed. The amount of wastewater discharged, 27.6 mgd, is greater than the amount of wastewater collected, 25.0 mgd, for a gain of 2.6 mgd. Hence, there is a net gain of 0.7 mgd for the watershed.

- The findings for individual subareas in the watershed are more telling. Of the 27 subareas in the watershed, only eight have a net gain of flow, 19 subareas have a net loss of flow. Of the eight subareas that gain flow, five of these subareas gain flow from having a wastewater treatment plant discharge in the subarea.

August 2000

- For this scenario, there is a net loss of 1.1 mgd for the Nashua River watershed or a net loss of 165.9 mgd if MWRA's and Worcester's withdrawals are included.

- Excluding Worcester's and MWRA's large water withdrawals, the net loss of water in the watershed is from the difference in water withdrawn (29.8 mgd) to water distributed (25.8 mgd), a loss of 4.0 mgd from the watershed. The amount of wastewater discharged, 23.3 mgd is greater than the amount of wastewater collected, 20.3 mgd, for a gain of 3.0 mgd. Hence, there is a net loss of 1.0 mgd from the watershed.

- This result differs from the annual findings, where there was a net gain of water to the watershed. This change is primarily from outdoor water use, which is a water loss from the watershed through evaporation.

- Water withdrawn in August (29.8 mgd) is 3.5 mgd greater than the annual withdrawn amount (26.3 mgd) primarily to meet the greater summer water demand.

- Of the 27 subareas in the watershed, 9 have a net gain of water and 18 have a loss of water.

Annual 2020

- For this scenario, there is a net gain of 0.3 mgd for the Nashua River watershed or a net loss of 157.2 mgd if MWRA's and Worcester's withdrawals are included.

- Excluding Worcester's and MWRA's large water withdrawals, the net gain of water in the watershed is from the difference in water withdrawn (30.0 mgd) to water distributed (28.6 mgd), a loss of 1.4 mgd from the watershed. The amount of wastewater discharged, 31.7 mgd is greater than the amount of wastewater collected, 29.9 mgd, for a gain of 1.8 mgd. Hence, there is a net gain of 0.4 mgd to the watershed.

- Water withdrawn (30.0 mgd) predicted in 2020 will increased by 3.7 mgd over the annual amount withdrawn (26.3 mgd) in 2000 primarily to meet the increase in water demand.

- Wastewater collection increases from 25.0 mgd in 2000 to 29.9 mgd in 2020, an increase of 4.9 mgd.

- Of the 27 subareas in the watershed, 9 have a net gain of water and 18 have a loss of water.

August 2020

- For this scenario, there is a net loss of 1.9 mgd for the Nashua River watershed or a net loss of 167.4 mgd if MWRA's and Worcester's withdrawals are included.

- Excluding Worcester's and MWRA's large water withdrawals, the net loss of water in the watershed is from the difference in water withdrawn (34.3 mgd) to water distributed (30.2 mgd), a loss of 4.1 mgd from the watershed. The amount of wastewater discharged, 26.9 mgd is greater than the amount of wastewater collected, 24.7 mgd, for a gain of 2.2 mgd. Hence, there is a net loss of 1.9 mgd from the watershed.

- Water withdrawals (34.3 mgd) predicted in 2020 will increase by 4.5 mgd over the August 2000 withdrawn amount withdrawn (29.8 mgd) in 2000, primarily to meet the increase in water demand.

- Wastewater collection is expected to increase from 20.3 mgd in 2000 to 24.7 mgd in 2020, an increase of 4.4 mgd.

- Of the 27 subareas in the watershed, 9 have a net gain of water and 18 have a loss of water.

9.5 Subarea Flow and Stream Flow

The average August and 7Q10 flows, for existing and future scenarios, were compared with predicted virgin flows in order to approximate the level of stress of each subbasin. DEM guidelines, as described in the draft memorandum: *Stressed Basins in Massachusetts* (Office of Water Resources, February 26, 2001) were followed to estimate the stress level of each subbasin.

The DEM has defined three hydrologic stress classifications:

- High-Stress: net outflow equals or exceeds estimated natural August median flow

- Medium-Stress: net outflow equals or exceeds estimated natural 7Q10 flow

- Low-Stress: no net loss to the sub-basin.

Based on these classifications, the stress levels for each subarea were determined for existing conditions (year 2000) as well as predicted conditions in the year 2020. Following the DEP stress classification system,

- One subarea—Flag Brook—is predicted to be high-stressed (net withdrawals exceeding median August flow) in the Nashua River Basin under either existing condition. Additionally, Monoosnoc Brook is predicted to be highly stressed in the future.

- Seven subareas are predicted to have medium-stress under existing conditions (net outflow equal/exceeding natural 7Q10): Quinapoxet River 2, Wachusett Reservoir, Monoosnoc Brook, Falulah Brook, Fall Brook, Wekepeke Brook, and Mulpus Brook. In the future, Quinapoxet River 1 and Catacunemaug Brook are expected to be added to the medium-stress list.

It is important to note that a large number of the subareas that are predicted to have some form of stress also contain multi-month reservoirs. These reservoirs are capable of storing large flows in the spring and holding them for use during low flow periods in late summer. Because of the stored flow, the impact of large demands in these basins may not be as great as the stress-classification system implies; it is possible that normal low flows are still being released from these reservoirs. To properly determine the stress levels in these basins, a more detailed study of each subarea is required.

Because the Wachusett watershed is highly managed for the Worcester and MWRA withdrawals, these withdrawals were not considered in the evaluation of stress in the Wachusett Watershed—a much more detailed analysis would be required to evaluate their uses. Instead, the calculations were based on other uses of water in the watershed, particularly withdrawals by Holden, Rutland, Princeton, Sterling, and West Boylston. Based on these withdrawals, three of the four subareas in the Wachusett Watershed were calculated to have medium-stress in the future.

9.6 Recommendations

The findings indicate that 11 of the 27 subareas in the Nashua River watershed are or will be in the future either high stressed or medium stressed under the DEM classification system. The stressed subareas are predominately in the Wachusett and North Nashua subwatersheds. The following is recommended for the stressed subareas:

- More detailed inflow/outflow analysis to assess the water balance of the multi-month reservoirs..

- Critical review of any additional water supplies from the stressed subareas.

- Emphasis on development and implementation of water conservation plans for communities with supplies in the stressed subareas, especially for those communities that do not meet the benchmark levels.

- Assessment of aquatic habitat impacts from worsening flow stresses.

- Critical review of any additional sewering in the basin, especially sewering that moves water out of a stressed subarea or out of the basin.

- Wastewater reuse or artificial recharge of wastewater discharges should be considered for any WWTP expansion in stressed subareas.

THE COMMONWEALTH OF MASSACHUSETTS

WATER RESOURCES COMMISSION

Policy for Developing Water Needs Forecasts for Public Water Suppliers

Effective Date: February 8, 2001

Introduction

This policy is intended to provide guidance to communities and public water suppliers seeking to increase the amount of water they currently withdraw from ground and surface supplies under the Water Management Act (WMA). The Department of Environmental Management, Office of Water Resources (DEM/OWR), works with communities, water suppliers, and their consultants to develop a draft water needs forecast for the permitting period. The draft volume amounts are reviewed and approved by the Massachusetts Water Resources Commission. Once approved, the water supplier should use these volumes in the application to the Department of Environmental Protection (DEP) for a Water Management Act water withdrawal permit.

Public water suppliers seeking water needs forecasts for their permits will fall into one of the three groups described below. Public water suppliers should review this information to determine which group most closely applies to their situation. In order to develop the forecast, DEM/OWR requires a basic level of information, as noted below. If the information is not currently available, water suppliers should recognize that there can be a considerable lead time in obtaining the needed information, and should plan accordingly.

Group A: Public water suppliers that have an existing Water Management Act Permit

In order for DEM/OWR to process a request for a new water needs forecast, the following conditions must be in place, or be substantially met:

1. The public water supplier must provide the following information for at least the last three years:
   (a) Water use information based on actual metering;
   (b) A break down of water use at least into residential, non-residential and unaccounted-for categories; and
   (c) An accurate estimate of service population, both year-round and seasonal.
2. Based on the information in #1:
   (a) Unaccounted-for water must not exceed 15% of the total system water use;
   (b) Residential gallons per capita day (gpcd) must not exceed 80.
3. The water supplier must have completed a Water Conservation Plan questionnaire.
4. The water supplier must demonstrate that all water conservation/system efficiency conditions, and other conditions, of the existing WMA permit have been met. DEP will confirm that the conditions are met or substantially complied with, or an approved plan is in place to meet the conditions in a reasonable and specified time.

The forecast will be brought to the Commission for review and approval.

Group B: Public water suppliers who do not have a Water Management Act permit

In order for DEM/OWR to process a request for a water needs forecast, the following conditions must be in place, or substantially met:

1. The water supplier must provide the following information for at least the last three years:

(a) Water use data based on actual metering;
(b) A break down of water use at least into residential, non-residential and unaccounted-for categories.
(c) An accurate estimate of service population, both year-round and seasonal.
(d) An accurate estimate of unaccounted-for water in the system.
(e) An accurate estimate of residential gallons per capita per day (gpcd).

2. The water supplier must have completed a Water Conservation Plan questionnaire.

The forecast will be brought to the Commission for review and approval.

Group C: Public water suppliers who do not meet the criteria for Group A or Group B

For public water suppliers that cannot meet any of the required criteria under Group A or Group B, DEP may issue a permit with an interim allocation of water. This interim allocation volume shall be based on the most recent years of water use by the Public Water Supplier (PWS) and will be developed by DEM/OWR in consultation with DEP. Factors that will be considered in determining the interim allocation include, but are not limited to, new users, climatic conditions, a change in system operations, and new metering.

DEP will require those permitted with interim allocations to collect and submit the data needed to calculate actual water needs forecasts within four years of the permit issuance date. DEP may also require the water supplier to provide interim reports containing the required information before the regular Five Year Permit Review. Upon submittal of that information, DEM/OWR will determine whether or not the information collected and provided is sufficient and accurate enough to develop a water needs forecast for the remaining years of the permit period. If DEM/OWR develops the forecast, and it is approved by the Water Resources Commission, DEP may permit withdrawal volumes that are consistent with the forecast.

Should the water needs forecast indicate that future demand is less than those volumes used in the interim allocation, DEP will allocate volumes through a permit modification consistent with those developed in the revised forecast.

Should the water needs forecast indicate that future demand will be greater than those volumes authorized in the interim allocation, the PWS may choose to apply for a permit for the higher forecasted need. If the water needs of the PWS can be met with the interim allocation volume, they may, with DEP's approval, extend the interim allocation until the next five year period of the permit or until the expiration date for permits in that basin.

Questions? Community officials, public water suppliers, consultants and others who have questions or would like clarification about this policy should contact one of the following…

Director, Office of Water Resources
Department of Environmental Management
251 Causeway Street, Suite 700
Boston, MA 02114-2014
mike.gildesgame@state.ma.us
617-626-1371

Program Manager, Water Management Program
Department of Environmental Protection
One Winter Street
Boston, MA 02108
duane.levangie@state.ma.us
617-292-5706

. . . or consult the DEP website at http://www/state.ma.us/dep/brp/wtrm/wtrmhome.htm and click on Publications

Appendix B – Water Supply Information

To View: Click on the town name to load that file.

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Community

Ashburnham
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Boylston
Clinton
Devens
Dunstable
East Princeton
Fitchburg
Gardner
Groton
Harvard
Holden
Lancaster
Leominster
Lunenburg
MWRA
Paxton
Pepperell
Princeton
Rutland
Shirley
Sterling
Townsend
West Boylston
West Groton
Westminster
Worcester